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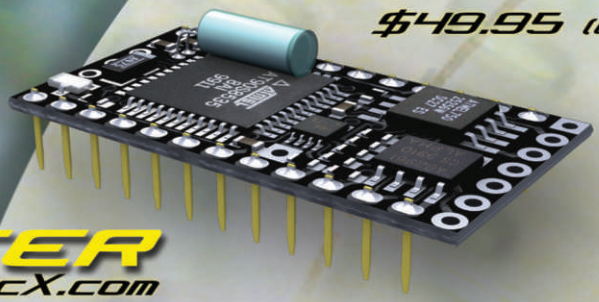

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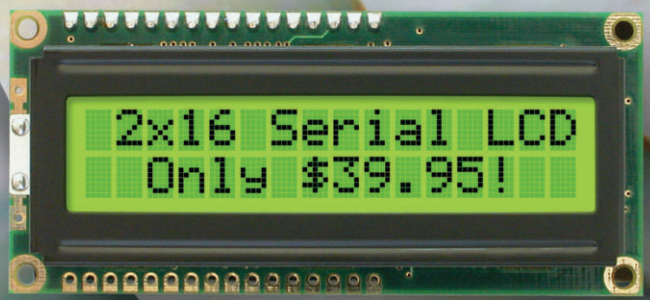

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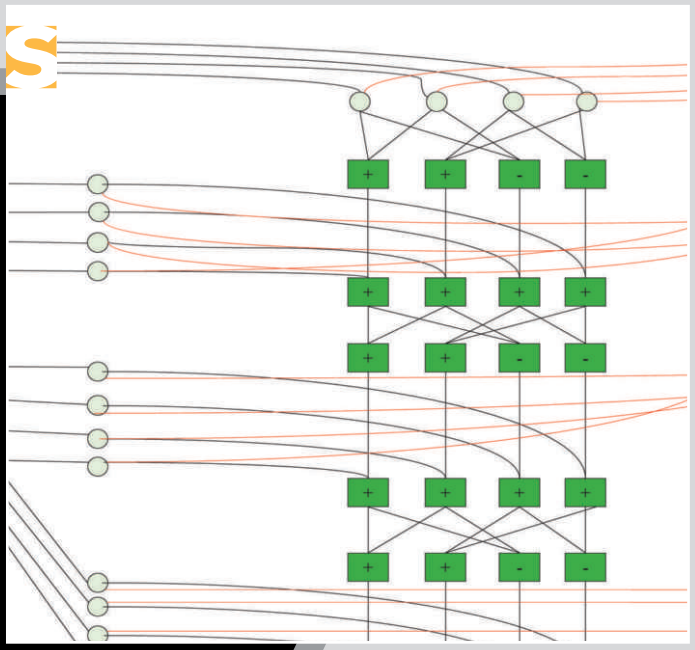

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Mind / Iron

by Dan Danknick

Back in 1986, a friend of mine showed me a 2D matrix that tried to rationalize the need for robots, without deprecating the usefulness of humans. On one end, humans were still good for reading, abstract thought, and non-linear problem solving. On the other, robots were the winners in undersea exploration, nuclear power plant inspection, and repetitive, mind-numbing tasks.

Ideally, robots will free us not only from dangerous tasks, but from the drudgery of daily life. When I recently interviewed Joe Jones of iRobot, he pointed out that, although the washing machine automates the wash, rinse, and spin operations, it doesn't alleviate our need to pay attention to the fundamental process — that of simply cleaning our clothes. So, bring on the robo-washer! Clothes could self-identify with RFID tags and an intelligent sorter could decide when to run a load. Such a robotic system would fuse existing technologies into a more useful product — one that serves to give its owner more free time. But, as a socially-conscious engineer, I need to ask what that time is best used for.

In some respects, I feel like much of that additional free time has been ignored by the personal robotics community. We have access to all manner of inexpensive CPUs, cheap servomotors, high capacity batteries, motion control coprocessors, fast interfaces, and an abundance of light materials. What do we do with this amazing pile of resources? Line following, sumo, and maze solving — the same things we've been doing for the past 10 years. Is this wrong? No, but I don't think it's a good use of the powerful resources at hand.

I recently exchanged Email with someone who wanted to write in *SERVO* about the Parallax M&M sorter, using the TCS230 color sensor. My reply was basically, "This has already been done. What else can we do with this color sensor that advances the art? What about, say, finding snails in the garden?" I figured I'd scared him off by calling him to a higher level of subsystem development, but, like most of you in our avocation, he bounced right back with a "blue sky" list of potential new applications. They included checking the color of automotive engine oil for wear indicators, adding a thin slit and then scanning to produce a 2D imager, detecting when a fruit has ripened, or when a slight color change in a leaf indicates that a plant needs watering. Now, this is the sort of thinking — and working — that we wish to promote in the pages of *SERVO*.

So, not being given to simply pontificate, next month we will announce our 2004 competition, Tetsujin. It's alluded to on Page 33 and you may be able to figure out the gist of what we're planning, but I'll bet you'll still be excited at the "full reveal" — not to mention challenged to use the resources at hand.

If we don't keep pushing forward, continually turning goals into tools, that 19-year-old 2D matrix will get lopsided very quickly. OCR, learning neural nets, and genetic algorithms are nipping at the heels of our historically human advantages. So, let's keep advancing the art. **SV**

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BIO→FEEDBACK

Dear SERVO:

I've been getting some Email about the description for wiring the potentiometers in the Hexatron article in the December issue. I made a mistake describing it — the middle wire needs to be connected to one of the outer terminals of the header connector. The values of the pots should also be 5 K ohms. I'm not sure if it's worth putting the correction in an upcoming magazine or not, but if you want to then, here is a diagram *(see Figure 1 below).*

Karl Williams, Author
via Internet

Dear SERVO:

Congratulations! I am super-impressed with the new magazine — a lot of great articles. I have been dabbling in robotics for more than a decade and I couldn't ask for a better magazine than this. Something I hope to see a lot of in *SERVO* is articles covering the Mini-Pod and Servo-Pod from New Micros, along with the Iso-Max language and Forth in general. (The centipede article appearing recently in *Nuts & Volts* is a perfect example.) Thanks for all you are doing.

Gary Wilson
Gatesville, TX

Dear SERVO:

I just received and read David Geer's GEERHEAD article in the January issue ("Modern Robots from the Past"). I really enjoyed the article and managed to learn a few more things on the history of AROK.

Mr. Geer, I hope that from time to time you will write other history of robotics articles. There are a ton of fascinating, but mostly untold, stories out there — both in the amateur, as well as the research/commercial realm. This history is gradually being lost.

I wonder what ever happened to Tod Loofbourrow and his Kim-1 based robot? What of Frank DaCosta's Robot Pet or Jonathon Kaplan's robots? Who could forget David L. Heiserman or Edward L. Safford, Jr.?

On the research/commercial front, what about the Hughes Aircraft Mobots or Jerry Rebman Electronics Co.'s GARCAN, or Quasar's Klatu? Finally, where did the GE Walking Truck and Hardiman suit go?

These are all but a *small* sample of the early robots from the 1960s and 70s — many people are completely unaware of these amazing early devices. An entire book could be written about this history, but it is slowly fading away (similar to the lack of record of early, pre-1970, amateur computing). Please keep it alive!

Andrew L. Ayers
Glendale, AZ

Dear SERVO:

I've enjoyed the first two issues of *SERVO* very much. It seems like every time I open one of them, I find an interesting article I didn't see before. Keep up the great work and I look forward very much to forthcoming issues.

Justin Womack
via Internet

Dear SERVO:

Hurray! Just what I needed for Christmas! *SERVO* is great and wonderful. I think all hobbyists, begineers, and experts, will read this one. Just one comment — some of the pictures are blurry. That's all.

Bassam Lababedi
via Internet

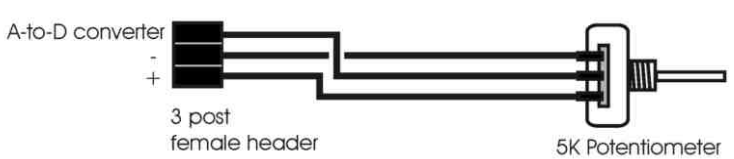

Figure 1

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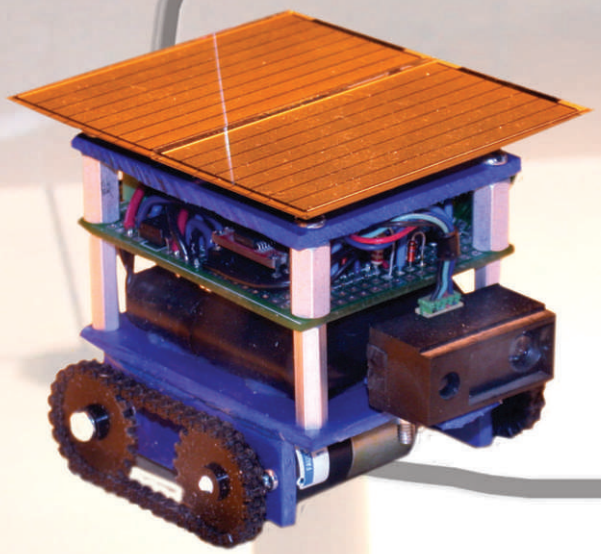
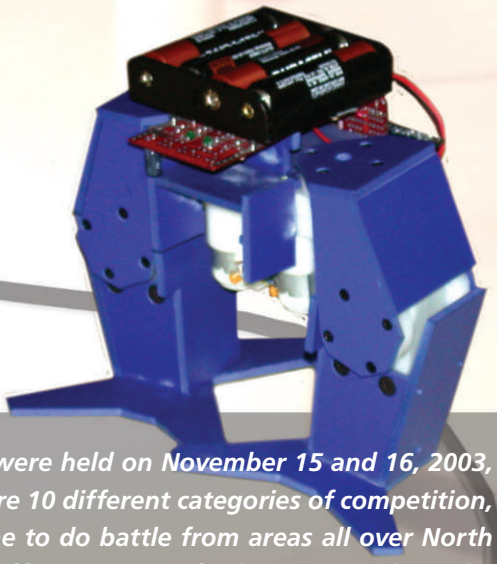
The Eastern Canadian Robot Games

by Karl Williams

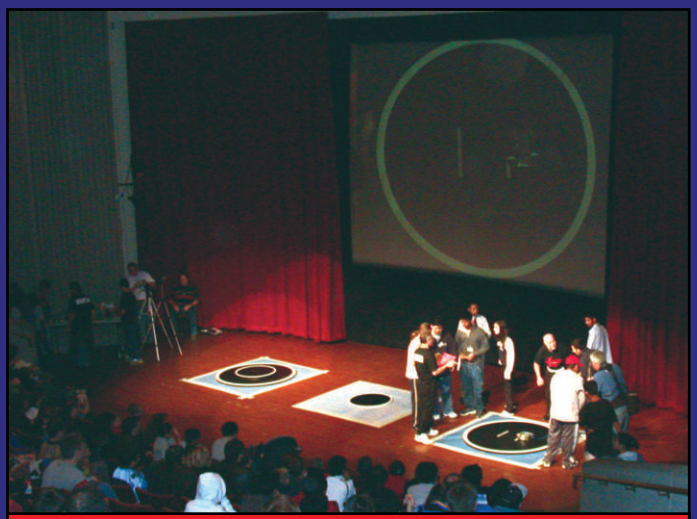




The Eastern Canadian Robot Games (www.robotgames.ca) were held on November 15 and 16, 2003, at the Ontario Science Centre in Toronto, Canada. There were 10 different categories of competition, with 150 robots created by close to 200 competitors who came to do battle from areas all over North America. There was a wide range of competitions from four different types of robot sumo, where the robots competed to push each other out of a ring, to firefighting, where robots searched through a maze to extinguish small candles. The purpose of the robot games is for people to have fun working with robotics, which is a great bridge to all areas of science and technology. It gives them a chance to get experience with electronics, programming, design, and mechanical construction by building real working robots that accomplish goals.

It was an exciting event with two new categories added to the already challenging areas of competition from last year. There was a new Line Following event and a new Masters Mini-Sumo category. Also new this year was a cash prize of $250.00 CDN for first place in the Masters Mini-Sumo and Fire Fighting (WellHead Blowout) competitions. The Sumo events were held in a large auditorium packed with many enthusiastic spectators watching the action on three sumo rings. There were also some interesting robots among the entries in the Art and Innovation category with a pneumatic walking robot chair, a tank style robot that fires tennis balls on command, and a miniature solar powered robot that lives independently in a sealed aquarium.

If you are feeling brave enough to subject your robot creations to competition at next year's Eastern Canadian Robot Games, I have given a brief description of the categories.



Robot sumos face off for battle in the main arena.

Fire Fighter

The objective is to build a computer controlled Robot that can move through a model structure, find a "burning oil derrick" (lit candle), and then extinguish it in the shortest time, subject to a few operating factors. This is meant to simulate the real-world operation of a robot performing a fire extinguishing function in an oilfield or home.

Mini Sumo

Within a 10 cm square column, build a robot sumo wrestler weighing under 500 grams to compete against other Mini-Sumo Wrestlers in a 77 cm ring.

A pneumatic walking robot is demonstrated to amazed onlookers.

Remote Control Sumo

This contest pits your creation against another robot in a field of combat where brute strength and cat-like reflexes combine to create the ultimate battle. The challenge is to create a robot whose sole purpose is to push, throw, flip, drag, or otherwise move your opponent out of a five-foot diameter circular ring within three minutes. This competition is the most popular of the events, both to watch and to participate in.

Photovore

Build a device that is self contained, solar powered, and goal seeking. Its physical dimensions must fit within a 150 mm (6") cube. Your only power source is a solarcell with a maximum area of 2442 mm2 (3.79 in2). The robot competitor will have to face off against other devices in a well-lit competition area, having to avoid obstacles and race to the middle. Once there, you must have your robot dominate the light pool until the end of the five-minute round.

Things are really heating up in the firefighting maze.

Solaroller

Given a maximum solar cell size of 806.5 mm2 (1.25 square inches), build a self-starting 150 mm (6") robot dragster to race one meter (3.3 feet) in full sunlight (or 1,000 watts Halogen lighting). Competitors will race each other down parallel 150 mm (6") wide lanes. The robot that is the fastest to finish or travels the furthest in three minutes wins.

Art and Innovation

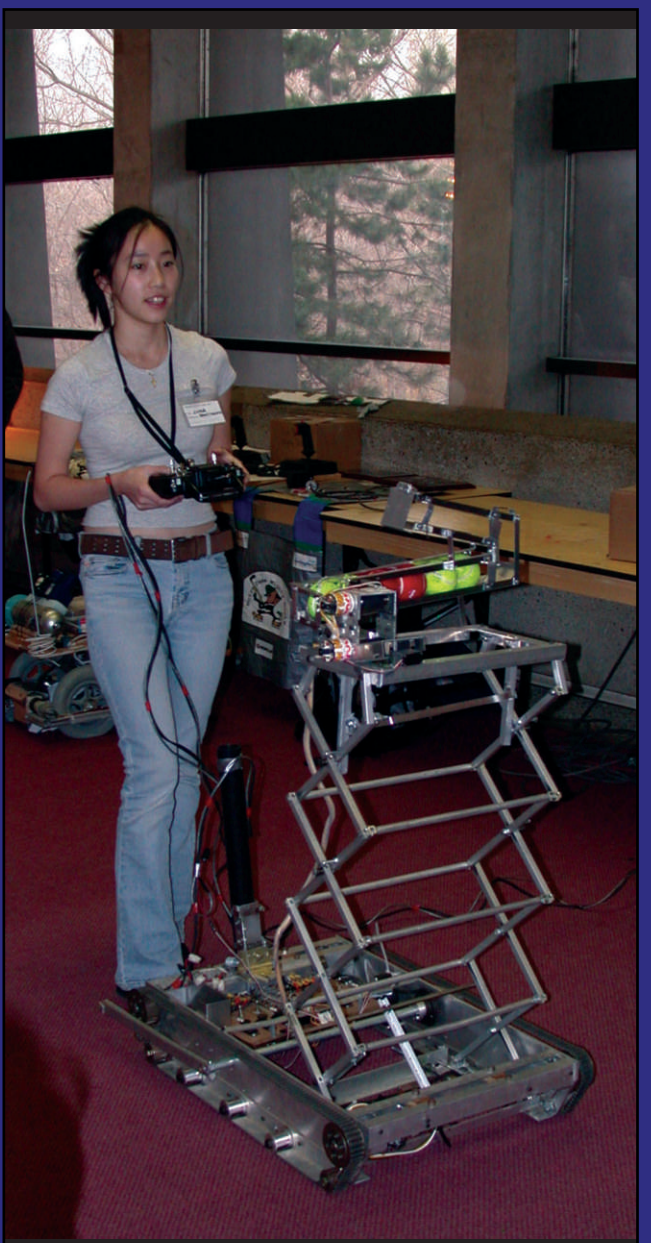
,Build a robot along aesthetically pleasing lines that does something deliberately by itself. The robot does not need a purpose other than being a work of art. If you come up with something innovative but not meant for the other competitions, then enter in this category.

Walker Triathalon

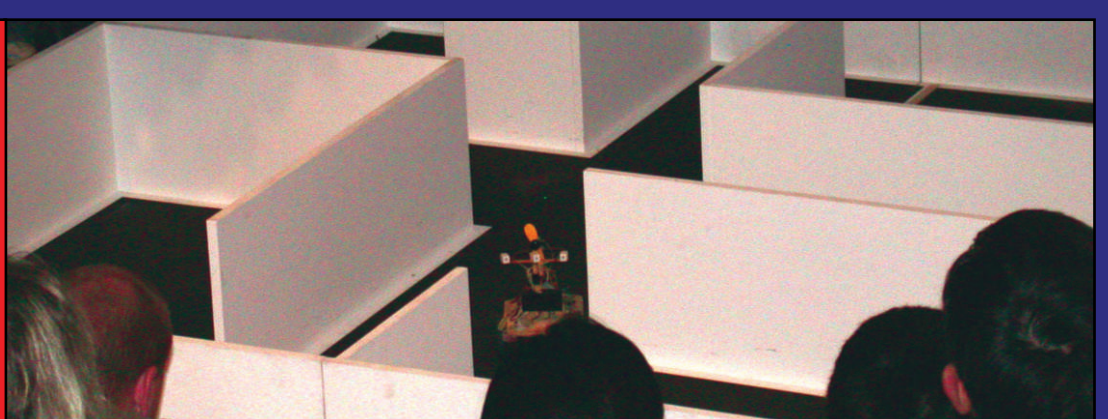
Legged robots face off against each other in speed/progress/ability challenges over various rough but equal terrains. Robots are awarded points based upon their ability to handle the broadest range of challenges. Competitors that accumulate the most capability points win.

Line Following

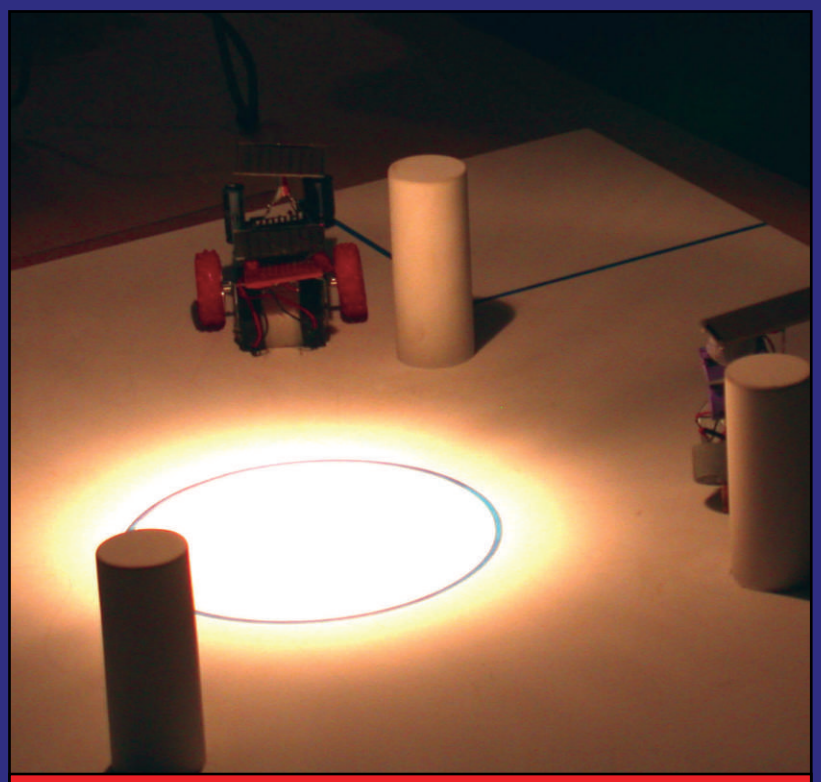
The Line Follower is a classic robot competition. The robots can use microprocessor control or simple digital or analog control systems. This event is intended to showcase basic sensor design and robot control systems in the form of small autonomous robots that must follow a black line over a white surface. Points are awarded based upon the distance covered and the speed of the overall robot. SV



An innovative combat robot fires tennis balls at spectators.



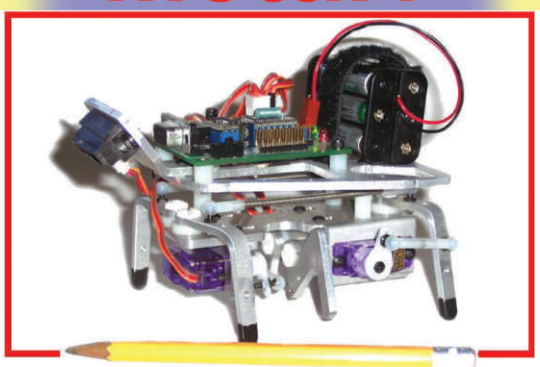
A firefighting robot searches for a burning oil derrick (candle).



Mini photovores race to dominate the light pool.

A well-designed robot cleans up in the line following competition.

Looking for a Little Metal?



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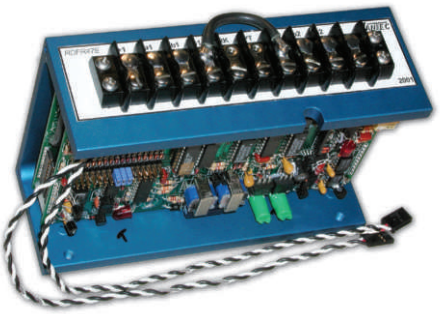

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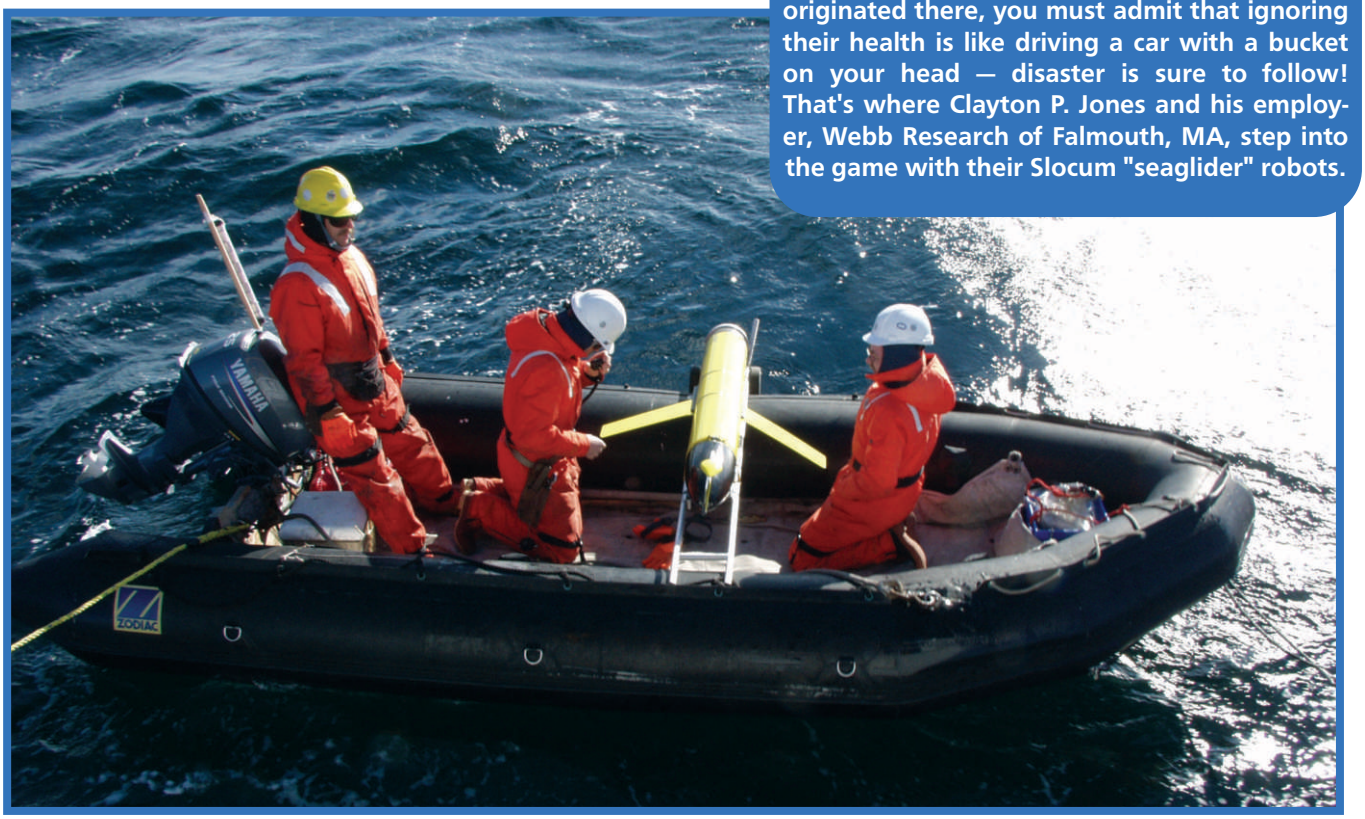
Gliding Through The Ocean

The Technology and Application of Buoyancy Driven Autonomous Vehicles

by Dan Danknick

Scientists clearly agree that if Earth's oceans die, mankind will surely follow. The ocean is an amazingly complex machine, operating far beyond the obvious role of biosphere for aquatic animals. It's an enormous thermal conductor and transport system at the surface, keeping the continents warm. As well, the world's oceans are a "burial ground," or sink, for carbon dioxide scavenged from the atmosphere (see References.) Even if you don't believe that life originated there, you must admit that ignoring their health is like driving a car with a bucket on your head — disaster is sure to follow! That's where Clayton P. Jones and his employer, Webb Research of Falmouth, MA, step into the game with their Slocum "seaglider" robots.

Images courtesy of Clayton P. Jones, Webb Research Corp.



These are the weather balloons of the oceans" explains Jones, a project engineer at Webb. The seagliders are designed to be launched in groups to execute a 3D pattern of data collection, used to model — and predict — ocean state variables. Each seaglider quantifies surface currents, sea surface height, temperature, and optical properties of the water. Each data set is tied to a GPS coordinate when the seaglider surfaces and updates its position.

The Machine

Surprisingly, these autonomous robots are not built like you might expect. Refer to Figure 1 for a schematic of the various acting forces, and how they are put to use in a novel way. To reduce "biofouling" (getting clogged with ocean crud), there is no propeller, just a fixed wing. Buoyancy is carefully trimmed near the center of mass — 5 mm close!

An electric mechanism inside the seaglider varies the buoyancy to cause it to sink or float. The angle of the wings imparts a horizontal component to this up/down motion, creating a saw tooth (triangular) path. Speeds as high as 0.45 meters per second can be achieved, and because of this unique method of "propulsion," they are quite suitable for projects requiring endurance.

Amazingly, there is even a prototype that uses 65-80% less internal power by omitting the displacement pump. Instead, it extracts heat from the differential across the thermocline to melt and freeze a hexane-derived compound and thus alter its buoyancy. This could be used in 1,000 meter deep dives for missions that span several years.

The Payload

As mentioned, the seaglider is normally used as an oceanographic profiling vehicle. So as a system, it is designed to support a wide range of hardware and software while collecting data from a variety of sensors. With a 10 inch removable payload bay, the customer (university, military branch, etc.) can install whatever they need.

Acoustic packages have also been used and include

hydrophones and mock towed arrays.

The seagliders are also of great interest to the military. They are virtually silent, have a small cross section, and are "slippery" in the water — which is good to reduce turbulence, as well as increasing battery life.

The Future

Jones explains that there will be a continuation of field experiments and incremental bettering of vehicles which will service the community. There is a constant push to increase the "information payload" through the improvement of sensors and their reporting.

There are also wide-scale deployment projects on the agenda, most notably the Argo Program which sets the goal of launching 3,000 seagliders to measure temperature and salinity in the upper 2,000 meters of the ocean. A primary focus of Argo is seasonal to decadal climate variability and predictability, but a wide range of applications for high-quality global ocean analysis is anticipated.

Perhaps Jean-Michael Cousteau explained it best in a keynote speech to Congress a few years ago. "With 95% of the oceans still unseen, exploration is the necessary first step. Exploration gives answers to questions we don't even know to ask." SV

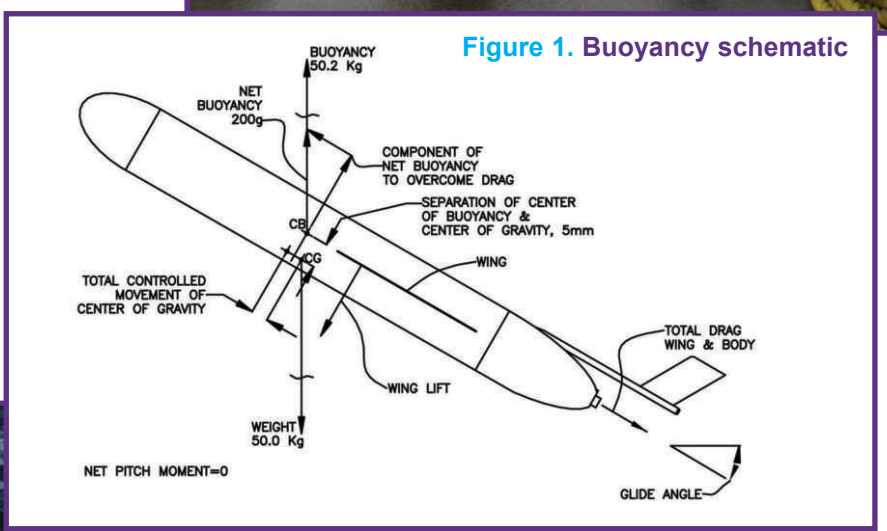
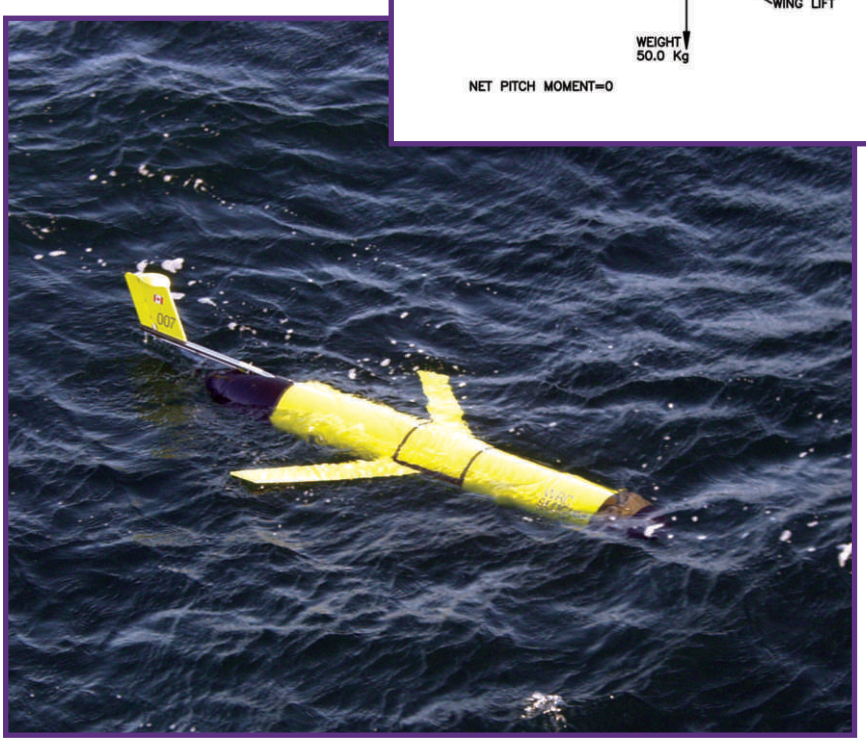


Figure 1. Buoyancy schematic



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by Pete Miles

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Q. Mr. Roboto, where do I find the aircraft aluminum that everyone uses in their robots you see on TV?

— Timothy
via the Internet

A. I can see how this can get confusing. I, too, have seen a lot of people describe the type of aluminum in their robots as "aircraft" aluminum. Aircraft aluminum actually represents a large family of different types of aluminum. The word "aircraft" is used because these aluminums are commonly used in aircraft. But, in reality, there is no single aluminum type that is called "aircraft" aluminum.

Different chemicals, such as silicon, copper, magnesium, and zinc, are added to the aluminum to alter its physical properties, such as strength, corrosion resistance, formability, weldability, and heat treatability, to name a few.

There are over 100 different grades of aluminum that are available. Because of this, the aircraft industry chooses the optimal type of aluminum for each of its unique applications.

The most common type of aluminum is 6061 aluminum because it is heat treatable (to increase or decrease its strength), has good forming and bending characteristics, good corrosion resistance, and is easy to machine.

Two of the most popular types of aluminum that are often called aircraft aluminum are 2024 and 7075. 2024 aluminum is about 20% to 50% stronger than 6061 aluminum (depending on the heat treatments), and 7075 aluminum is almost twice as strong as 6061 aluminum. 6061 aluminum is generally the cheapest aluminum to buy, whereas 2024 aluminum costs about twice as much as 6061, and 7075 aluminum costs about three times as much as 6061 aluminum. For most robotic applications, 6061 aluminum will have all the strength that you will need, is easy to machine, weld, and bend, is easy to find, and is the lowest in cost to use.

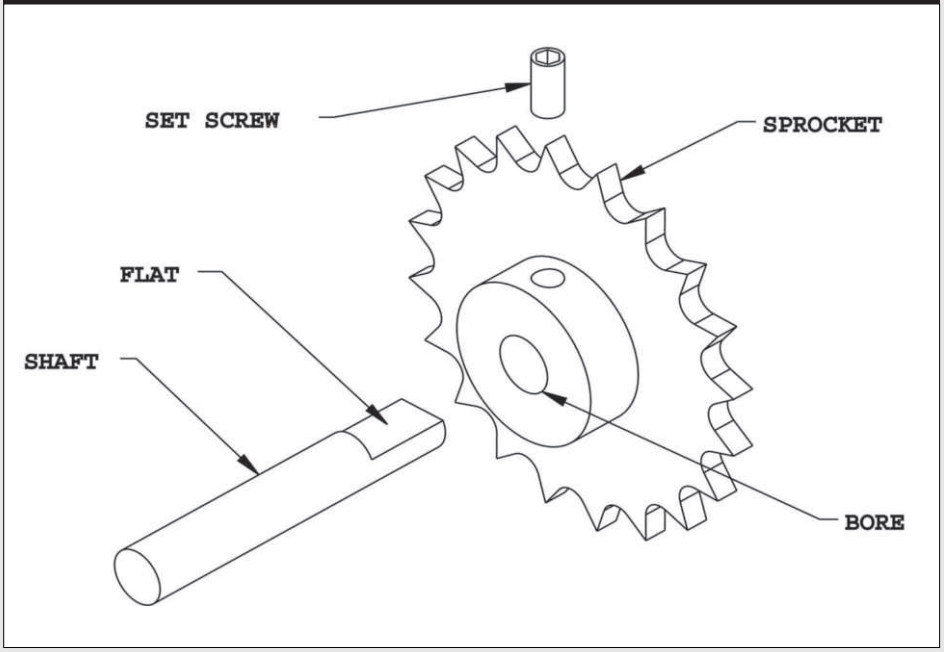
So, to answer your question, aircraft aluminum can be found at any metal supply house. All you have to do is ask for something a little more specific, like 6061, 2024, or 7075 aluminum.

Q. Mr. Roboto, I am having a hard time keeping the #25 sprockets on the shafts in the robot that we built at school. The set screws don't seem to hold on very long, and I have to use a file to smooth the shaft to get the sprockets back on all the time. Is there a better way to hold sprockets on the shafts?

— Mike Whitman
via the Internet

A. There are two different aspects to holding sprockets in place on drive shafts. The first and most important is the rotational aspect. This is what prevents the sprocket from

Exploded diagram illustrates a simple way to attach a sprocket to a shaft.



spinning/twisting on the shaft. The second is the longitudinal aspect, which is preventing the sprocket from sliding off the length of the drive shaft. #25 sprockets typically have a smooth bore and use one or two set screws to hold the sprocket on the drive shafts. To properly mount a #25 sprocket on a drive shaft, make sure that there is a flat surface ground filed on the shaft where one of the set screws will bear down onto the flat surface. The reason for doing this is that set screws do not hold very well on curved surfaces. When a set screw is bearing down on a round surface, the set screw is primarily using friction to prevent the shaft from twisting, which is usually smaller than the maximum force that is needed to be transmitted through the chain.

The frictional holding force can be increased by further tightening the set screw, but this ends up damaging the surface of the shaft since the set screw is being pressed further into the side of the shaft. This is probably why you are using a file to smooth down the raised deformations on the shaft's surface, so that you can put the sprocket back onto the shaft.

Though a set screw doesn't do a good job at preventing a sprocket from twisting on a drive shaft, it does help prevent the sprocket sliding along the length of the shaft. This is why many sprockets have two set screws. One set screw is used to prevent rotational motion, and the second set screw (usually rotated 90 degrees from the first set screw) is used to prevent the sprocket from sliding lengthwise off the shaft.

When placing a flat on a shaft, the width of the flat should be at least the diameter of the set screw, and not more than two-thirds the diameter of the shaft. The reason a flat surface works better is that, in order for the shaft to be able to twist inside the sprocket, the set screw has to be pushed out of the sprocket.

This requires the set screw to either work itself loose, or shearing of the threads around the set screw, which requires a significantly greater amount of force than sliding a set screw across the surface of a round shaft.

Most sprockets come with cup style set screws (the end of the set screw has an inverted cone). These set screws are designed to bite into a surface and make a ring shaped impression on a shaft. This is what helps prevent the set screw from sliding along the surface. One of the drawbacks to this type of a set screw (other than marring up the surface of the drive shafts) is that, when the shaft makes a lot of sudden direction changes, sides of the set screws slowly bite deeper into the shaft.

This eventually results in a gap between the set screw and the shaft, and then makes it easier for the shaft to twist inside the sprocket. This requires periodic maintenance to make sure the set screws remain tight. When working with flat surfaces, a flat head set screw can be used instead of a regular cup shaped set screw. Flat head set screws provide a better mounting surface, and do not mar the surface of the shaft, but they should not be used on round surfaces. I personally like using flat head set screws on motor shafts when I plan to attach and remove the sprockets many times during the robot development process.

Q. Dear Mr. Roboto, I've noticed more and more that microcontrollers and cool interface ICs use 3.3 V power supplies rather than 5 V as I am used to. How should I be interfacing the two? I don't want to blow anything up.

— Christoph Klein
Germany

A. This is a pretty good question. 3.3 volt circuits are becoming more and more popular as time goes on. I personally have never used any of the 3.3 volt components in any of my projects, yet. I think the real issue here is how the two circuits interpret the voltage levels between a high-to-low or a low-to high logic. A five-volt circuit might interpret a high signal from a 3.3 volt circuit as a low signal. So, when selecting the components, these transition levels need to be considered. I asked a friend of mine (Larry Barello) if combining the two different voltage level circuits is possible. He told

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me yes, but I would have to be careful in selecting the right components. He told me to look for five-volt tolerant versions of the 3.3 volt components. This is one of the first items mentioned in their data sheets.

The specific thresholds of both of the circuits need to be examined to make sure that the five-volt circuits will properly respond to the 3.3 volt circuit signals. As Larry pointed out many times, "there is no substitute for carefully reading the data sheets." They will tell you whether or not the logic levels will be compatible. Though this doesn't directly answer your question, stay tuned to future issues of this magazine. I am sure that we will see lots of articles explaining in detail how to integrate these two types of voltage circuits together since they are becoming more and more common.

Q. Dear Mr. Roboto, I am thinking about building a sumo robot using the Astroflight 915P gear motors. They have an impressive 800 oz-in of stall torque. But I am concerned that the 4 mm diameter shaft is too small for rough competitions. Is there a way I can determine if it is strong enough before I buy it?

— Dan A.
Corvallis, OR

A. I, too, have been looking at these Astroflight motors at **www.astroflight.com** 800 oz-in of stall torque equates to an impressive 50 inch-pounds of torque. With two of these motors, and using two-inch diameter wheels, this robot could potentially push about 100 pounds. This is awesome power for a six-pound sumo robot.

The real question comes down to how much torque can the motors actually apply to the output shaft without the wheels spinning on the sumo ring surface.

The easiest calculation is to estimate the worst case situation when you stall the motors. Since the no load speed of these motors is about 1,000 RPM using a 7.2 volt battery, some additional gear reduction (say, four to one) would be needed to keep the robot under control.

Because of this, we can assume the gearbox's output shaft will not be directly attached to a wheel. Hence, the primary stresses on the output shaft will be due to torsion (twisting).

The equation shown here is used to calculate the maximum torsional stress in a solid round shaft, where τ (tau) is the stress (in PSI), T is the torque (in pounds), and d is the diameter of the shaft in inches.

$$\tau = \frac{16\,T}{\pi\,d^3}$$

For a worst case calculation, use the stall torque of 800 oz-in (50 in-lb). Thus, the maximum stress in the four mm (0.157 inch) diameter shaft will be 65,800 PSI!!!

This is an extremely high shear stress for most materials. To prevent permanent damage to the shaft, it would have to be made out of a material that has a yield strength greater than 120,000 PSI.

This would require that the output shaft be made from a high strength alloy steel. I personally would question if this shaft is strong enough to support repeated stall loads without eventually failing, but this is a worst case situation.

Realistically, a top-notch competitive sumo robot would start spinning its wheels when pushing 30 pounds. With two-inch diameter wheels and a coefficient of friction of 1.0 between the wheels and the ground, a single motor would see about 15 inch-pounds of torque. Thus, the maximum stress in this shaft would be about 20,000 PSI. This is low enough that most steels and stainless steels will be strong enough to support it without any damage.

These are just quick and dirty calculations to determine torsional stresses in a shaft.

The worst case calculation is always the best place to start. If the shaft is strong enough to support the worst case application, then it will be fine. If it doesn't, then you will need to use what the actual operating conditions are. If you can keep the torsional stresses below 20,000 psi, then most steel and stainless steel shafts will be strong enough to support the applied torques.

If the stresses are too high, you can reduce the applied torque through gear reductions or increasing the diameter of the shaft. The best place to determine if the motor is actually strong enough to do what you need it to do is to contact the manufacturer of the gearbox.

Keep in mind that many times the reseller of the gear box does not know these details or who the actual builder of the gearbox was, so a bit of research may be needed to chase down this information.

Q. Mr. Roboto, what factors must be taken into consideration when charging NiMH batteries? What about lithium ion? What are the best rechargeable batteries now?

— Timothy J. Leon
Vacaville, CA

A. The main factor that must be monitored when charging NiMH batteries is the battery voltage during rapid charging, because a constant current charging method is used. Rapid charging is when the charge current is between 0.5C to 1.0C (C represents the mAhr capacity of the battery).

Trickle charging is when the charge current is between 0.033C to 0.05C. During rapid charging, if the individual cell voltage reaches 1.8 volts, the charging process must stop, switch to a trickle charging method, or the battery can be damaged. During the charging process, the battery voltage must be monitored continuously.

When an individual cell's voltage drops 5 mV to 10 mV from the highest measured voltage, the battery is fully charged, and the charge should either be stopped or switched to a trickle charging process. This is known as Delta V charging. Monitoring the Delta V (the 5 to 10 mV drop) shouldn't start until 10 minutes after the charging process begins.

Lithium ion batteries are a bit more complicated since voltage and current must be monitored. At the beginning of the charge, it uses a constant current charging process. If the individual cell voltage is less than 2.9 volts, the charge current should not exceed 0.1C. When the individual cell voltage is above 2.9 volts, the charge current should be 0.7C.

When the cell voltage reaches 4.2 volts, the process switches over to a constant voltage charging process. When the current drops down below 0.1C, the charging process is completed. During the charging process the temperature of the batteries must be monitored, and if the cell temperatures exceed 45 degrees Celsius the charging process must be terminated for safety reasons. What are the best rechargeable batteries now? Well, that depends on what you want to do with them.

Lithium ion batteries have the best energy-to-weight ratio with NiMH batteries coming in second, and NiCd batteries coming in third. Lithium ion batteries are small and deliver about 3.3 to 4 volts per cell, thus fewer cells are needed to power a circuit. NiMH and NiCd batteries can source very high currents, much higher than lithium ion batteries. Generally, lithium ion batteries should not source more than five times their rated capacity, or a fire may occur.

Both NiMH and NiCd batteries can source over 20 times their capacity without too much trouble, other than reducing the life of the battery. NiCd batteries should be stored in a discharged condition, whereas NiMH and lithium ion batteries do not need to be discharged prior to storage.

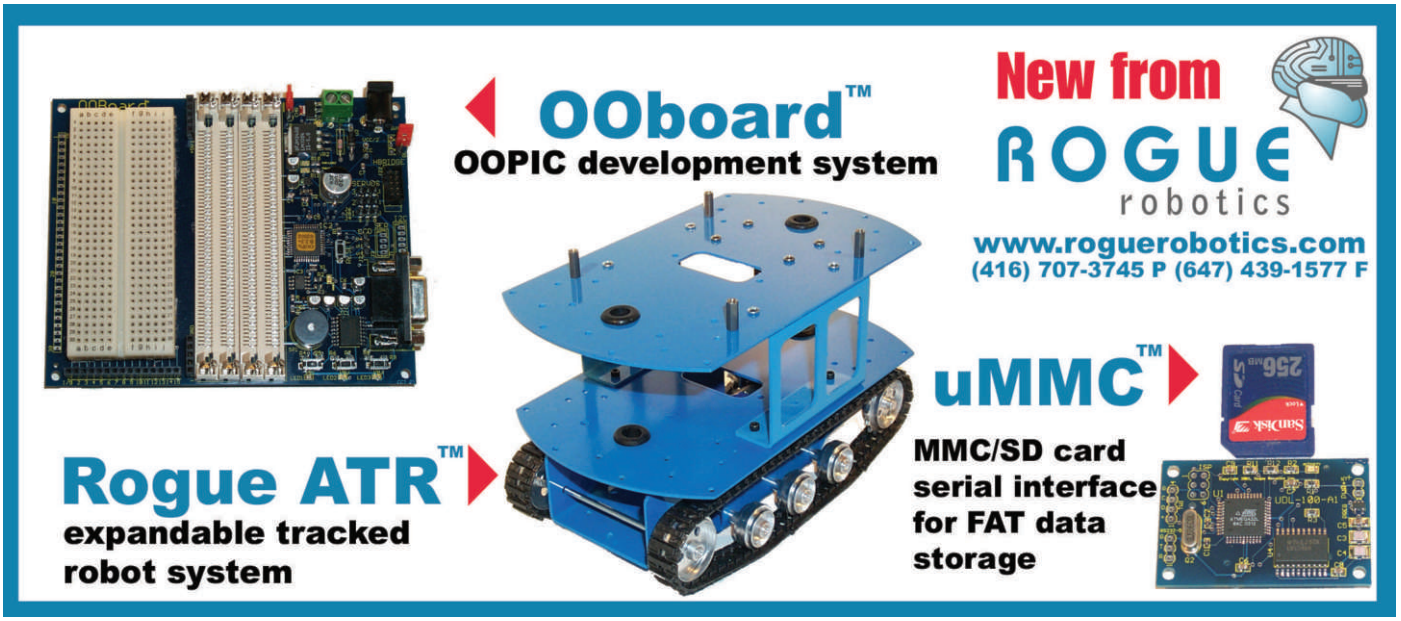
Lithium ion batteries lose about 10% of their remaining capacity (self-discharge) per month. NiCd batteries self discharge at about a 20% rate, and NiMH batteries lose about 30% of their remaining capacity each month in storage.

Lithium Ion batteries do have a shelf life of about two years, after which their performance starts to degrade regardless of how they were used.

NiMH and NiCd batteries can be severely abused during charging and discharging, whereas lithium ion batteries can catch on fire during excessive charging and discharging cycles. If weight is a major issue, then consider using the lithium ion batteries.

If high current sourcing is required, then look into using either NiCd or NiMH batteries. Otherwise, all three battery types will probably do fine for your needs. Keep in mind that right now you cannot purchase individual lithium ion battery cells because of the danger of fire if they are improperly charged or discharged.

This is why they are sold as battery packs and these battery packs come with their own built-in discharge and charge protection circuits. Use these circuits to protect the batteries. SV



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NETWORKS of NEURONS

by Michael Robinson

The brain is composed of billions of cells called neurons ...

What is a neural net you ask? You're probably already thinking, oh, it must be a network based on neurons, and you're right. A neural net is a form of AI based upon the modular neurological structure of the human brain. The degree of trueness to the structure of the brain, and therefore advanced learning ability of neural networks, is completely dependent on its design.

There are two major types of neural network: software based and hardware based. Each type has its pros and cons, but over the course of this article, I'll concentrate on a hardware based net for its trueness to the human brain and extreme flexibility. But before I go into the AI details, let me explain a bit about how the brain works. (You mean your mom hasn't told you how your brain works?)

The Human Brain and Neurons

The brain is composed of billions of cells called neurons, each of which has its own 'learned' factors; see Figure 1. They have one logic-deciding factor — their threshold value — and one non-logical factor — their connection pattern. Throughout this article, I'll refer to neurons as **Nx** for simplicity, so remember, keep an eye open, you never know when a neuron might try to wipe out your memory ... seriously.

Every neuron is connected to at least one other neuron on both of its ends; see Figure 2. Let's focus on neuron **NC**, whose only purpose in life is to transfer an electrical signal from his pals **NA** and **NB** to **ND** when the signal meets a certain requirement.

This requirement is called the neuron's *threshold*, and in the case of the brain, it is the voltage level of a signal from **NA** or **NB**. For now, I'll pretend the neurons work in integral voltage levels to make things simple, although in reality, they work in the minute millivolt range. Let's declare **NC's** threshold is 13 volts, for now.

Every neuron must be connected to at least two other neurons, one on each side, but you're probably still wondering how exactly these connections are set up. Well, neurons are set up in an additive fashion: when the inputs are added the sum is compared to the the threshold. If the sum exceeds the threshold, it will be transmitted to the next neuron after **NC**, which, in this case, would be **ND**. To utilize these neurons, your brain then arranges them into a connection pat-

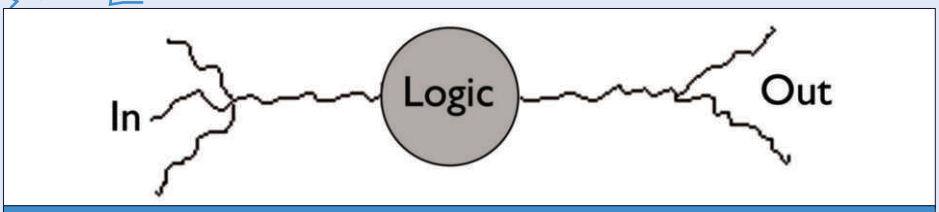


FIGURE 1. An actual neuron

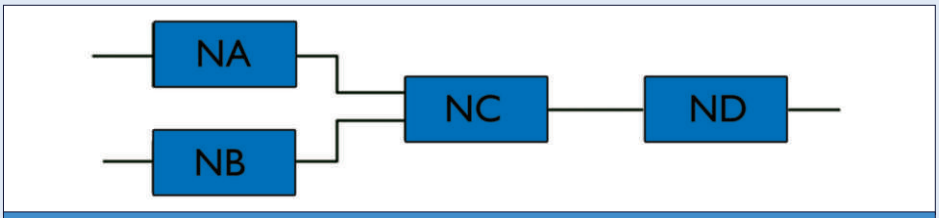


FIGURE 2. A connected set of neurons

tern similar to the one you'd use to set up logic gates, which we'll use as the basis of our upcoming project.

Let's use Figure 2 again as an example and say that **NC's** threshold is still 13 volts. Now suppose **NA's** outputs 14 volts. Since this meets **NC's** 13 volt threshold (14 + 0 = 14), **NC** will output the same 14 volts to **ND**. Now let's say **NB** outputs five volts. Because this doesn't meet **NC's** threshold (5 + 0 = 5), no signal will be transmitted to **ND**. Lastly, let's say **NA** outputs 14 volts and **NB** outputs five volts simultaneously. This meets **NC's** threshold (14 + 5 = 19), so 19 volts will be output to **ND**. Because these neurons (and any others) can be implemented in any fashion, with any threshold value, there are nearly endless possibilities, and learning capabilities, of the human brain.

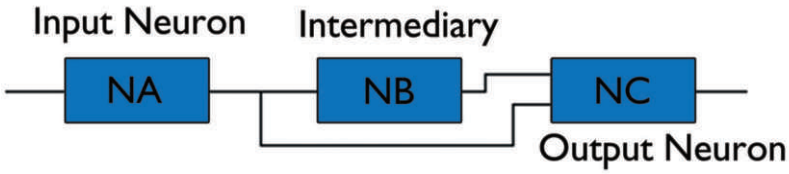
A Simple Example

To show how your brain uses this structure to store your knowledge, let's use the following example. When you were in first grade, you learned the letter 'A' corresponded to the sound "aah." This knowledge was stored by your neural network in the following way: Your teacher told you 'A' would have to be pronounced "aah," so your brain linked neurons to your eye which would recognize 'A.' It then linked neurons to your tongue muscles for "aah." Lastly, it implemented a connection pattern between the two groups of neurons through the use of additional neurons and their thresholds. While you were busy painting some Picasso-like stick figure, your brain was busy at work storing this information.

Now, when your eyes see anything, they forward it to your input neuron for 'A' (among others). The 'A" neuron uses its companion neurons to determine whether what your eyes have seen is an 'A' (see Figure 3). If the value for 'A' is 16 volts, the threshold value of your input neuron **NA** will therefore be 16 volts. If it reaches the threshold, it is then output to the next neuron, **NB**, which then verifies it's not higher than 16 by having an increased threshold of, say, 17. Your **NC** neuron takes these two inputs and compares it to its threshold value of 16. If it is indeed 'A' (16 + 0 = 16), then **NC** will output 16 to your tongue neurons, which will then use a similar procedure to control your tongue muscles.

You can prove this concept by inputting a false value such as 12 to your 'A' input neuron. As you can see immediately, neuron **NA** will not react to any values below 16. Furthermore, **NB** will prevent any values above 16. This arrangement allows only the value of 16 to prevail, and is your brain's way of implementing logic through neurons.

FIGURE 3. 'A' neurons



The Hardware

At this point, you're thinking, great, but what does this have to do with electronics? Remember I said neural nets could either be hardware or software? Well hardware neural nets are — you guessed it — made from hardware, namely logic gates and transistors, while software nets are composed of software languages, such as C++ or Prolog, to name a few. In future articles, I plan to go step-by-step through the construction of an actual hardware neural net that can learn up to 16 different things keyed to four digit binary numbers. Before we do that, let's look at how the human brain relates to the artificial neural net we'll build.

Near the beginning of this article, I said neural nets are based on the modular neurological structure of the brain. Therefore, our net must integrate many artificial neurons (which are modular by nature) of different thresholds, into an alterable connection structure. But our artificial neurons will be logic gates, their thresholds will be the *type* of gate, and their alterable connections will be an array of transistors capable of selecting a connection to the next neuron.

This network of logic gates is the closest hardware neural network that still contains an element of practicality. Since one learned task requires a combination of eight logic chips — which include AND, OR, and Invert functionality — we'll implement a microprocessor, RAM (Random Access Memory), and ROM (Read Only Memory) to

store multiple learned configurations. This will limit our nets learning capacity only by its ROM size and logic hardware which, in this case, would be 16 tasks, since our logic hardware can only support four-bit binary (16 combinations can be derived from four bits, and yes, you can upgrade it to eight bits by doubling the logic hardware).

Logic Gates

Most of us use logic everyday without ever realizing it, because it is simply impossible to live an adequate life without it. Just like us, computers and electronics use logic for all of their tasks. The difference is that they use a type of 'dumb logic' separated into a few different types: AND, OR, and Invert. Since we're covering hardware here, I'll jump straight to the electronics side of logic: the logic gate.

The logic gate is a gate, if you will, that only opens when certain requirements are met. Each gate has different requirements, so I'll start with the AND gate. The AND gate outputs a binary 1 (high) only when both inputs are a 1 (see Figure 4). The OR gate outputs a binary 1 when any input is 1. Lastly, the Invert function converts the input number to its binary opposite. As you can see, all of the above gates and functions are dumb, but when combined, can be set up to create an artificial brain with the ability to learn.

In a future article, we'll work further on our neural net design. Until then, read Google's **comp.ai** and **comp.ai.neural-nets** groups for further information on neural nets and AI in general.

Since we didn't cover the software type of neural net, if you're interested in this, you should check out "Neural Networks with Java" at **http://rfhs8012.fhregensburg.de/~saj39122/jfroehl/diplom/e-index.html**

And if you have any questions, please feel free to Email me at **mhr_54@cox.net** and I respond to all messages – so don't hesitate! SV

FIGURE 4. Three basic logic gates

AND

Input		Output
1	1	1
1	0	0
0	1	0
0	0	0

OR

Input		Output
1	1	1
1	0	1
0	1	1
0	0	0

Invert

Input	Output
1	0
0	1

Ready to go in deeper? ...

Then read about the Hadamard Transform on page 52.

This article is not about digital pheromones, text to facial expressions, or the synergistic effects of Facial User Interfaces (FUIs). It is not about the large number of possible applications for the Expressive System for Robotic Animation (ESRA) platform. This article is about how teenagers in one New Jersey high school developed a system for a robotic user interface that observers with no previous knowledge of the system could understand.

Robots That 'Teach'

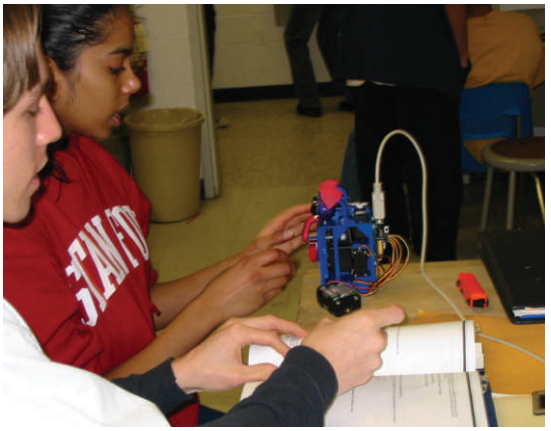
— ESRA Motivates —
Kids Relate To It As A Funny Friend

by David Peins

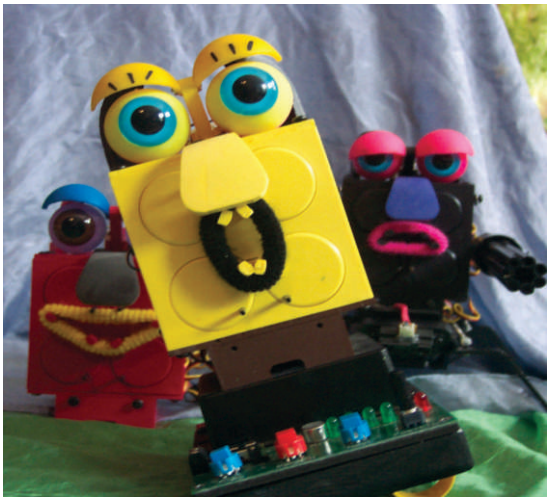
When using ESRA in the classroom, the temptation to misuse the technology is high," says ESRA's creator, Brian Patton. If you have any doubt, try placing text-to-speech on a computer that students use every day and see how long it is before you start hearing unexpected messages coming from your computer's speakers.

Science and Engineering students at Manalapan High School take a full year of Electronics in their Junior year. The electronics class introduces students to electronics as a practical art, a way of using electronics for scientific applications. The 140-hour course teaches students the theory and application of electronics (Ohm's and Kirkoff's laws, Thevinin's theorem), the practical and safe use of meters, oscilloscopes, and power supplies, and how to design and breadboard circuits. Finally, students learn to design and produce printed circuit boards in the lab.

After covering the basics, electronics classes are presented with a problem that is unique and challenging. Last year, they were asked to create digital pheromones using transmitters and sensors, so that robots could recognize and interact with each other. Four ESRA robots were provided by Robodyssey and introduced to the students. ESRA is a robot that is clearly not human. It is non-threatening — how could anyone be afraid of something with a scrunchy for a mouth and soft, floppy eyelids? It is unpretentious — it is itself. Yet, it is recognizable at all levels of human interaction as a face — familiar, intentionally comical, but friendly. It is manipulated by four hobby servos and can be controlled with many commercially-available products.



For this project, we chose to control the servos with a Netmedia BX-24 controller mounted in a Robodyssey Advanced Motherboard. The BX-24 programming language is a variation of Visual Basic, so the syntax is familiar to many, and is useful for future projects. The Robodyssey Motherboard allows servos and sensors to plug directly into the BX-24.



To model a communication scheme for transmitters and receivers, the students first thought of cockroaches, ants, and wasps when they heard the word 'pheromones.' They concluded that humans also have the ability to communicate with these signals, but real pheromones would be too complex for the amount of time they had for the project. Humans learn to recognize what facial expressions mean at a very early stage in their development. However, this would mean that the robots would have to recognize facial expressions.

Although the students agreed that humans get many cues from facial expressions, there are other communications being exchanged that are less obvious, including pheromones. Robots could communicate at this simple, invisible level without actually seeing the expression on the other robot, while the robot users could observe the expressions.

There was little time for students to learn to design complex sensors in such a basic course, so they decided to use simple IR LEDs and receivers to transmit and receive each unique frequency for each age/gender robot. Because the students had more experience in programming, the solution was primarily a software one. (science and engineering students take a half year of computer programming in the 9th grade, and AP Computer Science in their junior year, including C++ and Java.)

With a communications scheme agreed on, students assigned a familiar role to each robot, and assigned an emotional reaction, characterized by a series of facial expressions, for each interaction. Students also assigned an age and gender to each — an 'Old Male,' a 'Young Male,' an 'Old Female' and a 'Young Female.' The class discussed what facial expressions they might observe in each of the 16 possible interactions. How do members of a specific age group react to each other and to members of a different age group? For example, how do old men act toward young women and young women toward old men?

With 16 stereo-typical responses agreed upon, students redefined the problem as 'how to make ESRA mimic those expressions so that an outside observer could recognize to which age and gender group each ESRA belonged.' In any classroom,

when students ask their teacher to teach them, education becomes a partnership between the teacher and the students — a learning environment, not a teaching situation.

Students asked questions like, 'How do you control the facial expressions of this robot?', 'What are servos?', 'How does one robot sense another robot?', and 'How will we store a series of behaviors and recall them when confronted with another robot?'.

After learning how to control the servos on the robots to produce the desired expressions, students wrote code that would cause the desired reaction when each robot was face-to-face with another robot. (Student code examples can be found at **www.robodyssey.com/students/esra/codeexamples** and on the *SERVO Magazine* website at **www.servomagazine.com**)

In a completely different situation, ESRA was introduced to high school student Kylan Turner. Her growing interest in computer programming and her desire to help children with autism has led to a trial use of ESRA in a school for children with learning differences. Kylan's infectious enthusiasm has also led to an interest in robotics throughout her school.

What's Next?

This year, students will be given mobile robots and encouraged to make only simple, discrete transmitters and receivers and perhaps only simple analog controls, modified by the presence of pheromones. Each robot will have a specific task and, with the help of other like-minded robots, perform more complex tasks. Simple i ndividual rules, complex adaptive behavior — in short, a swarm! **SV**

ADDING SEXES TO ROBOTS

■ The Challenge: Adding Sexes to Robots?!

To transform four ESRA robots into individual beings that can be identified as a young male, old male, young female, or old female by an outside observer. No visible modifications could be made to the robots that might hint as to which one is male or female, young or old.

■ The Solution: They Aren't that Easy!

This task was given to a group of high school students as a way to secretly lure them into learning a variety of practical skills. First, the students had to agree on how a robot would behave in proximity to another robot. In other words, how a young male responds to a young female vs. an old female. Secondly, the students had to learn how to manipulate the ESRA's servos to emulate human expressions. Thirdly, the students had to develop a software-based communication system to allow robots to identify themselves to the other robots by simply being in the same area. (Something we call digital pheromones.) Lastly, the students had to tie this all together in code for every combination of associations for each of the four robots.

■ The Future: An Exciting World!

So, what happened? The students learned an enormous amount of material relating to computer science, electronics, and even a bit about social behaviors. On a deeper level, we realized we were opening a door to an exciting and unexplored world of developing sexually dimorphic robots. We began to realize that some day, as robots become more and more integral to our daily lives, robots will be able to identify who we are. Robots may exhibit different personalities depending on the situation they are in. Perhaps a robot mixed in a crowd will show emotions not only relating to the task at hand but even the personal space it shares with its human counterparts.

ETHICS IN ROBOTICS?

Now, we want to increase the challenges and potentially deepen the plot. An increase in variables will add to the complexity of the response. What if the young male is in the presence of his "father?" Should a robot have a favorite color? Should a robot have "personal space" depending on its gender? All these variables can be addressed simply by adding more sensors. The question and the challenge is, how do we treat the data? The answers will be both interesting and stimulating. It might even give a glimpse into something besides our computer, we might even be peering into ourselves. ■ ■ ■ ■

Author Bio - David Peins has taught every shop area, from machine tool to graphic design. He has worked in many diverse industries as a machinist, drafter/designer, machine shop supervisor and laborer.

He currently teaches Electronics at the Science and Engineering Specialized Learning Center at Manalapan High School in Englishtown, NJ, and is President of Robodyssey Systems, LLC, Trenton, NJ — **www.robodyssey.com** He can be reached at dpeins@ieee.org

ESRA Inventor Block - Brian Patton, creator of the ESRA mechanism, was inspired after seeing MIT's KISMET on a PBS special.

Discouraged by his wife's rejection of the idea to spend $25,000.00 to build a robot just like KISMET, he set out to create a slightly more affordable design. Brian eventually joined Robodyssey Systems and ESRA became the fun and educational tool it is today.

WHAT'S A PHEROMONE?

Biologists describe a pheromone as any substance produced by an organism that serves to induce a physiological or behavioral response in another individual of the same species. When given the task of creating pheromones, students thought of insects and sex attractants, alarm substances, trail markers leading to food sources — you remember, like Sim-Ant! So, pheromones are simple substances excreted, not generated by higher levels of thought, and not necessarily left behind, that can induce a complex response in another organism of the *same* species.

Allomones affect members of a *different* species and are favorable to the emitter, like a flower's smell attracting pollinating insects. Kairomones also affect members of a *different* species and benefit the recipient, rather than the emitter, like the scent of prey to the predator.

■ What's a Digital Pheromone?

It's an electronic device that sends out a simple, coded message over and over, and is little burden on the robot's higher-level logic processor. The transmission could be through infrared light, radio frequency, ultrasound, or something else, and it would not affect or be affected by, other systems in the environment.

Students working with ESRA started with individual emitters for each age/gender robot but ran out of time (the entire project only lasted five weeks) and elected to use the processor to code, as well as decode their infrared emitters. Receivers could also be discrete devices that only turn on when in the presence of a pre-programmed digital pheromone, relieving the processor of that task.

■ What are They Good for?

Complex adaptive behaviors can arise from the reception of simple digital pheromones or combinations of simple digital pheromones. In the case of the students working with ESRA, the behaviors that students decided on for each encounter of a specific age/gender robot was coded into a BX-24 microcontroller and caused the robot receiving the pheromone to exhibit a series of eye and mouth movements. These could be interpreted by observers (with no prior experience with the robots) as a specific age/gender clues. ■ ■ ■ ■

AIRBORNE AND WATERBORNE ROBOTS

Let's see, what do we have here? Oh, yeah — state-of-the-art robots that fly, take to water, and some you can build!

The Age of the Flying Robot is Here!

Flying robots, Homeland Security, and the Department of Defense (DoD) need you. And so necessity finds a way. Unmanned Air Vehicles (UAV) have been called on to fight terrorism and the war in Iraq. Examples, you ask? Yo, looky here.

The Predator

The Predator is most often deployed in scenarios of medium risk. Wherever we can send a robot instead of putting our sons and daughters in harm's way, the Predator can go. If it's shot down or plummets into the ocean, we've lost a Predator, not a life.

The Prey

Originally created to do recon, the Predator has taken out targets, as well (Al-Qaida members, Afghanistan, Nov. 2002).

The Program

The Predator system has roots in the Gnat 750 air vehicle, sensor technologies, and ground control and data transfer technologies. One Ground Control Station (GCS) and one Trojan Spirit II Satellite Communications (SATCOM) system control four Predators.

When not moving under its own power, the Predator is dismantled and packed into a shipping container called a Coffin. When the Predator awakens to soar the skies, it receives communications from the GCS and the SATCOM (which, by the way, doesn't require line of sight).

The SATCOM system enables the transmission of images and voices from the Predator to the GCS. Yes, the Predator is watching and listening!

The Predator program is led by the Air Force. Predator served in Kosovo in 1999 in an intelligence and target locating capacity. Since 2001, Predator has been armed in Afghanistan. The Predator was first deployed in Europe in 1995.

PREDATOR

The Predator also carries ordinance.

Photo courtesy of Steven Aftergood, FAS

Robotics of the Predator

The Predator is 100% off-the-shelf mechanics and avionics. It takes pictures from the air using two color video cameras and is equipped with radar.

The Predator delivers on near real-time video transmissions from its cameras, viewable by ground control. The

Global Hawk seeing the sights.

Global Hawk at rest. What a pretty bird!

Photos courtesy of Steven Aftergood, FAS

Predator is operated from a remote station with full cockpit gear. The pilot on the ground can see directly in front of the plane.

The Oomph! Factor

Made by General Atomics Aeronautical Systems **(www.uav.com)**, the Predator boasts a 101 HP engine, is shorter than a modest yacht at 27 feet, and can move at up to 135 MPH.

Computer Brains

The Predator's computer systems include the Mercury RACE (it mans the radar). It has high performance Digital Signal Processing (DSP). The multiple processor system is scalable, which is useful as the needs of the Predator grow.

Global Hawk

How much more robotic can a metal bird be than to fly itself? Not much more than Global Hawk, made by Teledyne Ryan Aeronautics. The ground crew watches their instruments as Global Hawk goes it alone — with no forward camera and no commands from below.

It Can't Say Hemi

But it can say Rolls-Royce! A Rolls-Royce Allison jet engine is just one of the things that makes this bird a sweet singer. With over 7,000 lbs. of thrust, that's a lot of wing flapping. It has three kinds of eyes — infrared, radar, and optical — that record images around the clock.

The Global Hawk UAV flies solo, piloted by two onboard computers. It downloads its mission, ground control hits the start button, and kicks back to watch as Global Hawk takes off, flies, and lands better than any pilot on record. Whether longitude, latitude, altitude, or attitude, these co-piloting computers manage all that — which makes them all that. Every wing and spoiler is under their control. While the mission plan tells them what the mission is, the computers decide how to best carry it out.

Global Hawk on Tour (*of Duty*)

Ground control monitors the computer brains' decisions as the mission proceeds. Algorithms and other technologies enable Global Hawk to respond to the unexpected. Global Hawk is prepared for disaster through automated emergency plans.

Multiple plans are available to deal with all types and severities of problems that can occur. Global Hawk can assume a holding pattern, decide on altered mission plans (in tandem with ground control), return to base, or make emergency landings.

The BAT III

The BAT III **(www.spyplanes.com/bat3.html)** mini-robot-plane rips out of sight and returns on its own. Demonstrations held for the military

BAT III

The BAT III, ready for takeoff from an SUV for a demo at NASA Ames Research Center's Moffett Field.

Photo courtesy of Hank Jones, MLB Company

include sending the bot out of contact to successfully return solo. There is no monitoring system.

Like a dog or cat you let out to do its thing, you wait for the BAT III to complete its mission and come back home.

Making Itself Useful

The BAT III flies up to 100 miles one way. It can collect detailed images of individuals on the ground, down to what they hold in their hands. It can circle an area or structure, surveilling for up to six hours, and no one would know it was there.

Though the BAT III must be maintained like any other plane, once it has completed a specific mission pattern successfully, it can repeat it over and over.

The BAT III Flies Upside Down

The BAT III has a new engine and propeller combo for increased power. Instead of climbing like a plane, it takes off like a rocket!

During an early takeoff with the new engine, it flew straight into a wall of wind. Seconds after takeoff, the ground controller saw the plane's nose upside down; the BAT III had been forced into an unscheduled loop.

Robots Inspired by Swimming Things

Some robots closely model the well-known water creatures they resemble.

Much of what we call life is so-called in part because it can move. In the case of these waterborne bots, you will be in awe of how intelligent their mobility appears.

The brighter they are, the fewer the characteristics that distinguish them from those real amphibious creatures that we marvel at ... or fear.

"Sssssssssssssss!"

The robot snake project (see Karl William's book under Resources) makes a truly snake-like creature that wouldn't serve badly as an autonomous watchdog, er, a watch-snake.

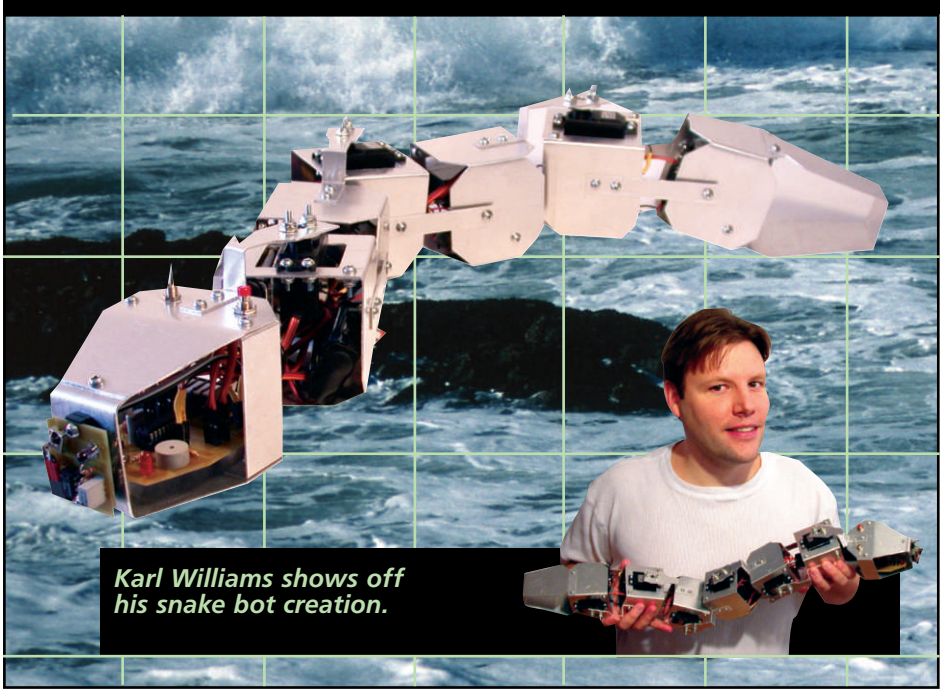
Its mere presence would be enough to scare a significant percentage of prowlers away. (While I'm at it, if I were to dig a mote around my house and let all four of Karl's projects live there ... hmmm?)

Where Was I? Oh!

The robot snake is made of six wriggly subsections plus a head to make up its seven lucky moving parts. Each segment is powered by its own R/C servo.

Now that has got to provide some unique movements, friends. (Say, how many segments with servos can you build into your snake and program it? That sounds like a challenge to me. In fact, I think it is!)

SNAKE *Snake bot winking at you just before he eats you up!*



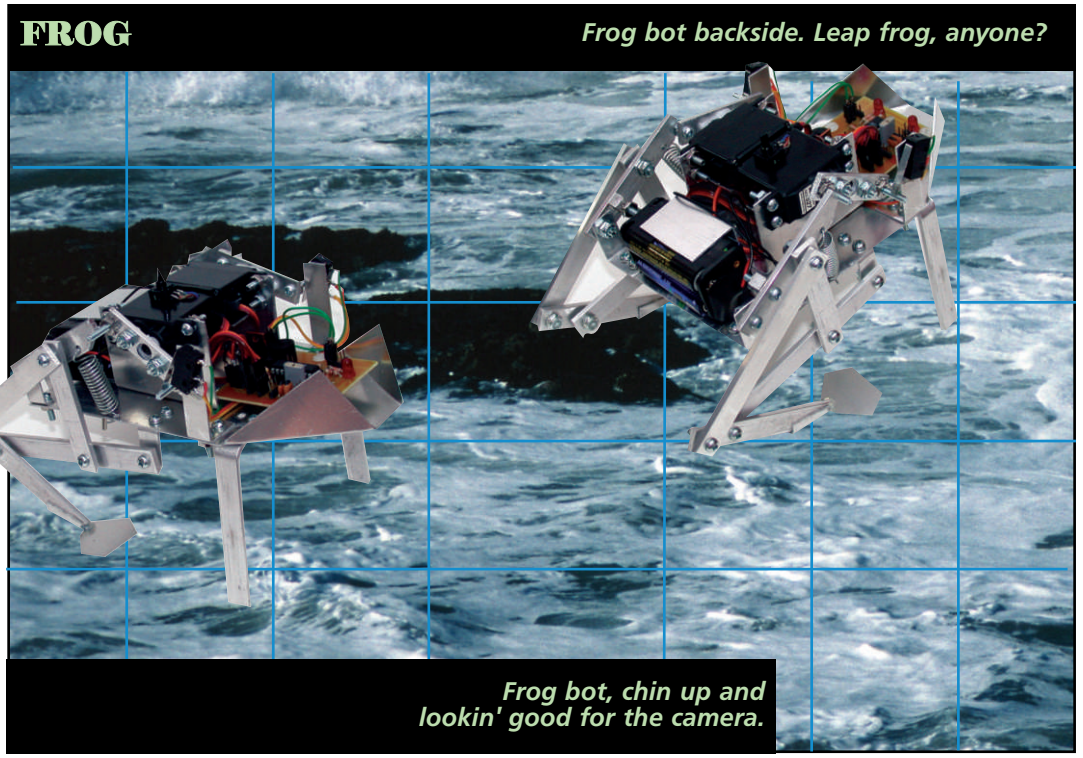
Karl Williams shows off his snake bot creation.

How Does it Do That?

So how do you make a robot slither like a snake and not a servo-driven mistake? (Say that three times fast and you win ... uh, nothing). Actually, you make it so the segments each alternate with their buddies front and behind, like so.

Now let's see, uh, the one segment goes up when the next one goes left (or is it right?). Then, the next one goes down and the other one goes right (or left? Hmmm?). You get the idea.

The result is a snake bot that motors on the same principle as the genuine reptile we all know and leap from on sight. It also changes directions to avoid objects using infrared. Other than stops for recharging, it could virtually move on forever. The snake bot also rolls and side-winds.



A Slimy Tale of Snake-Bot Mayhem!

Karl Williams, creator of many a waterborne bot, once brought a robot snake to work. The robot slithered through the laboratory, evading objects and changing directions, when, suddenly, it turned toward a woman. Though Karl had brought his metallic amphibians in before, the woman was caught off guard and leapt away screaming. It's easy to momentarily forget that these aren't real creatures with wills and appetites of their own!

A Croc Bot (Not for Cooking)

Four legs, a head, and tail — yep, it's a croc all right, and not the kind you simmer gumbo in all day. This wirelessly controlled metallic monster mimics a crocodile's four-legged movements with ease.

No Hair!

Well, it's a tortoise, so there must be no hare, right? (That's why they call it a pun and not fun, okay?) The turtle bot is a masterpiece of multiple technologies. With its ultrasonic sensor and optical shaft encoder, it can map its environment and then move around in it (and, more like the hare and not like the tortoise, it moves very fast!).

Frog Legs a la Servo, Anyone?

Not if he hops away. The frog bot moves ... like a frog, by jumping.

He can head out West over mountainous (okay, slightly rocky) terrain. The timing with which you fire off each of its separate leg movements adjusts the robot's course.

stimulate your bot with Java™

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RidgeSoft™ modern tools for intelligent robotics

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NEWS (*and Other Things*) in the Air

A lot of R&D is devoted to military production models of Vertical Takeoff and Landing (VTOL) flying robots. Reports are that they look like everything from flying shop vacs to giant insects. MLB Company (**www.spyplanes.com**) has assembled both VTOLs and amphibious autonomous airplanes.

Today's military VTOL can fly down the street, stop, hover, and check out buildings, properties, and rooftops. They can carry small weaponry, which could conceivably be used for crowd control (I surrender!), convoy escorts, or high-risk assault missions.

As you read this, the military is on the verge of developing VTOLs small enough to land in treetops and spy on surrounding areas.

"My name is Tom Servo and I'll be your pilot today."

Though it's been kept under wraps (perhaps in hopes that we won't stop flying), there are already thousands of flying robots in use around the world. Yes, that commercial airliner you or your loved one may have recently boarded is totally automated and has been for years.

The only exception is take-off, not because it can't be automated, but because pilots might get their feelings hurt if they couldn't still do it (takeoff being the easiest of tasks).

Roboshark

Roboshark I (and now II) are the creations of Andrew Sneath, submarine designer and shark enthusiast. Roboshark has a "porpoise" in life — to mingle with real sharks, take their pictures, and study them.

And no, I wouldn't assume the sharks don't know the difference, especially if there are any attempts at mating, but they accept the submarine-like pretender into their environment; in this way, Roboshark can collect data never before known or verified about these undersea carnivores.

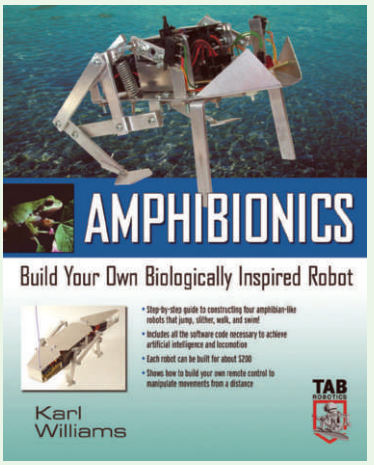
Roboshark II — Robo Stats

This formidable specimen measures 6'6" and weighs in at 78 lbs. Like a sub, it moves using thrusters, guided by an onboard computer and sensors. At a speed of 3 MPH, Roboshark matches its biological counterparts move for move as it cruises, dives, and rises again. It can dive to 30 meters and resurface. Roboshark II is remote controlled and works as a shark observer at the UK's National Marine Aquarium.

Convergence

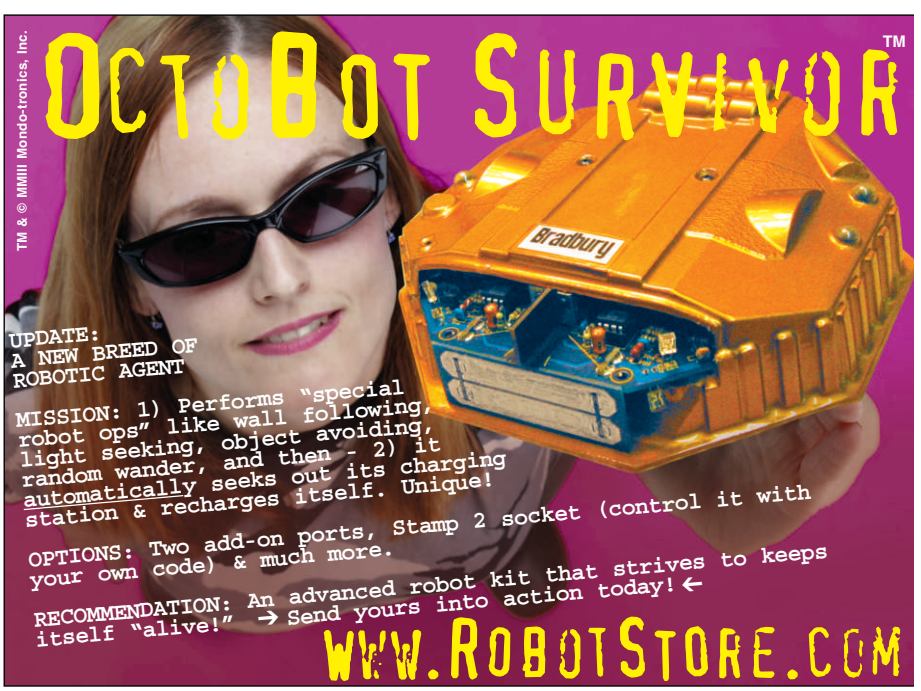
How long before we see robots (military or otherwise) that can swim, fly, walk, crawl, hop, and climb? Will you be their creator? SV

Resources



Karl Williams' new book, ***Amphibionics*** from McGraw-Hill/TAB Electronics.

http://books.mcgrawhill.com/cgibin/pbg/007141245X.html



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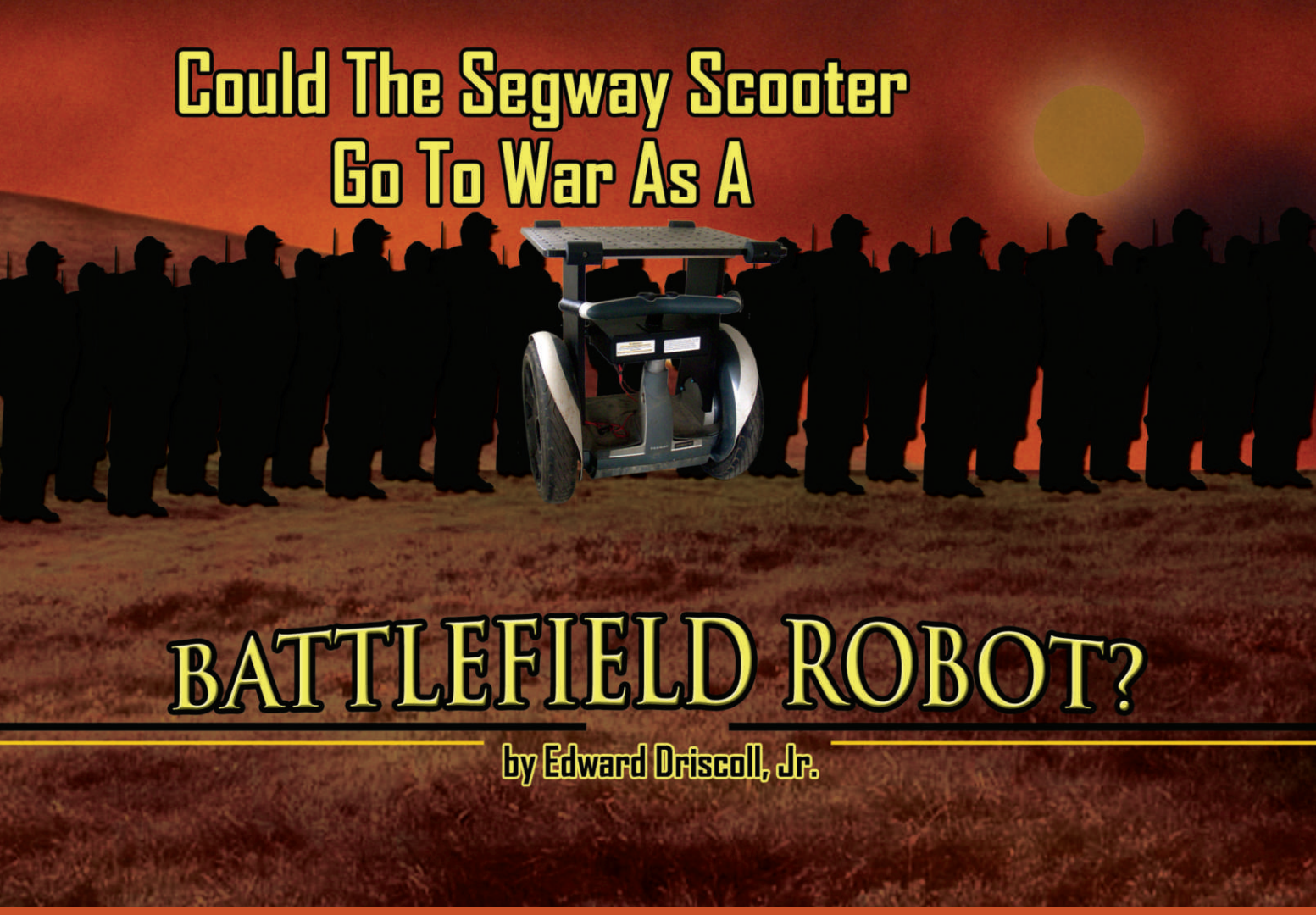
Could The Segway Scooter Go To War As A BATTLEFIELD ROBOT?



by Edward Driscoll, Jr.

Battlefield robots, for many, conjure up images of gleaming Terminator-like androids marching in lockstep and firing lasers and rockets into the night. But not surprisingly, their earliest applications have been somewhat more utilitarian.

Research in battlefield robots has been going on for several decades, but the need to see them deployed in the field has increased exponentially following 9/11, and the realization that in the Middle East, a potential terrorist could be lurking on every street corner.

On December 1st, 2003, the many thousands of daily readers of the popular Drudge Report news site (**www.drudgereport.com**) saw a headline that said, "Pentagon explores battlefield robots ..."

Adding a further level of science fiction-like flavor to the Associated Press story that Drudge linked to (available at **www.space.com/businesstechnology/technology/segay_defense_031201.html**), is the fact that the Segway is playing a starring role in it. The hope is that the two-wheeled, gyroscopically balanced scooter can be successfully automated, and its platform adapted for a variety of functions, including battlefield search missions transporting injured soldiers to safety, or following soldiers to haul their gear.

Even before the Segway officially debuted in December 2001, it had had an amazing amount of buzz surrounding it. While it's very unlikely that the device will change the world in quite the same way that its inventor, Dean Kamen, hopes it will, it's nonetheless a remarkable piece of engineering.

So, it's no surprise that just as the automobile, motorcycle, and airplane have seen plenty of battlefield use over the last 100 years, DARPA (the Defense Advanced Research Projects Agency; **www.darpa.mil**) would consider what role the Segway could play, as well.

The Man from SPAWAR

Helping to lead the way in this research is Commander H.R. "Bart" Everett, USN (Ret.), the Associate Division Head for Robotics at the Space and Naval Warfare Systems Center (or SPAWAR for short — their homepage is **spawar.navy.mil**), located in San Diego, CA.

Everett (whose personal website resides at **www.geocities.com/ResearchTriangle/Campus/2859**) was formerly the director of the Office of Robotics and Autonomous Systems at the Naval Sea Systems Command in Washington,

DC. He's been involved in mobile robotics research since 1965, with over 80 technical publications and 19 related patents issued or pending, and has personally been involved in the development of 14 mobile systems.

Everett says that adapting the Segway is just one of about 20 ongoing projects that the SPAWAR is involved with. And that number is growing, "because the number of applications has expanded, due to the world situation, obviously. And the technology has matured tremendously, so there are actually some doable scenarios now, whereas before, robots in the military were a little premature."

Tactical and Security Applications

"Our biggest involvement over the years," Everett says, "has been in physical security-type systems that go inside of warehouses, and then also outside on the roads, patrolling fixed-installation sites, like Army depots or shipyards, or Air Force airfields; things of that nature. We've been working in that area for a little over 10 years."

As a result of 9/11, SPAWAR has been involved in more tactical applications, as opposed to security. They're focusing much of their research on what Everett calls force protection scenarios, to assist troops in Iraq and Afghanistan.

How do tactical scenarios differ from security applications?

Everett says that prior to 9/11, robots geared toward security had been designed to be installed in bases in the continental US. "So you had the advantage of being able to tailor the infrastructure to the installation, and do everything you needed to do. And it [the robot] was there, basically, to detect intruders that were coming in to steal things."

In contrast, "tactical scenarios relate more to battlefield-type situations, where you're going into somebody else's country, and you don't own the terrain, and you do things over there differently, because you don't have the luxury, say, of going around and installing all of your paths for the robots, and testing them all out, making sure they all work, and then telling the robots later to execute those paths."

Everett pounds home the biggest difference in his mahogany-like southern drawl: "Somebody's going to be shootin' at you while you're doing that, so you have to be able to do things differently."

Adapting the Segway

This is where the Segway comes in. SPAWAR is looking to adapt it towards tactical missions in the Middle East. "The nice thing about the Segway," Everett says, "is that it's only two wheels, as opposed to three or more, and so you can traverse over a lot of things that you can't do in say, a tricycle configuration. Your mobility is just short of incredible".

However, Everett says the biggest limitation of the Segway is the same thing that caused early models to be recalled in September 2003: its batteries give it about two hours of runtime. And when the batteries die, it tips over.

But even with those limitations, Everett says, "it's a very nice design," adding that it's capable of scooting around at surprisingly high speeds (civilian Segways have their speeds capped at about 12 miles per hour, but the unit itself is capable of moving at about 25 MPH, perhaps even more). "They're very controllable under the right conditions, say indoors or on outdoor terrain. Even on rugged terrain, they offer some tremendous advantages, because they have very large wheels, and can climb over a lot of stuff without a small caster getting snagged on a curb. And then they can turn around in place and come back down. We've been able to traverse 45-degree inclines with an actual human onboard, so they're extremely robust."

According to Everett, in some circumstances, the Segway's tremendous mobility clearly offsets its disadvantages, "and those are the applications that we're looking at." And while DARPA has a number of proposals for putting them to use, Everett says the vote is still out on whether it will actually be deployed. "There's nothing that's emerged yet as an earthshaking, 'this is clearly a scenario where the Segway really outperforms everything else.'"

One Possible Mission

On the SPAWAR website there's a series of photos of the Segway leading a group of smaller robots. Everett says that the purpose of that project is to test and develop a few capabilities, the first of which is to be able to go into a building with no prior information about what the layout is. "So it has to go in and map the building, auto-reference off the map as it builds it, and not get lost."

About SPAWAR

SPAWAR's mission is to provide the warfighter with knowledge superiority by developing, delivering, and maintaining effective, capable and integrated command, control, communications, computer, intelligence and surveillance systems. And, while our name and organizational structure have changed several times over the years, our basic mission of helping the Navy communicate and share critical information has not. SPAWAR provides information technology and space systems for today's Navy and Defense Department activities while planning and designing for the future.

Another application that SPAWAR is looking into is using robots as repeaters to extend RF communications. On missions where soldiers penetrate thickly walled structures with robots — particularly caves and bunkers — they reach a point where signal strength drops off so much that they can no longer communicate with the outside. So a larger robot can carry, or lead, several robots to distribute RF repeaters. "When the signal starts dropping off, you just have one of the slave robots in the train stop at that point, stay there, and act as a repeater. When the signal starts to degrade again, you drop another one off at that point. You essentially string these repeaters out behind you like breadcrumbs and maintain your communication path."

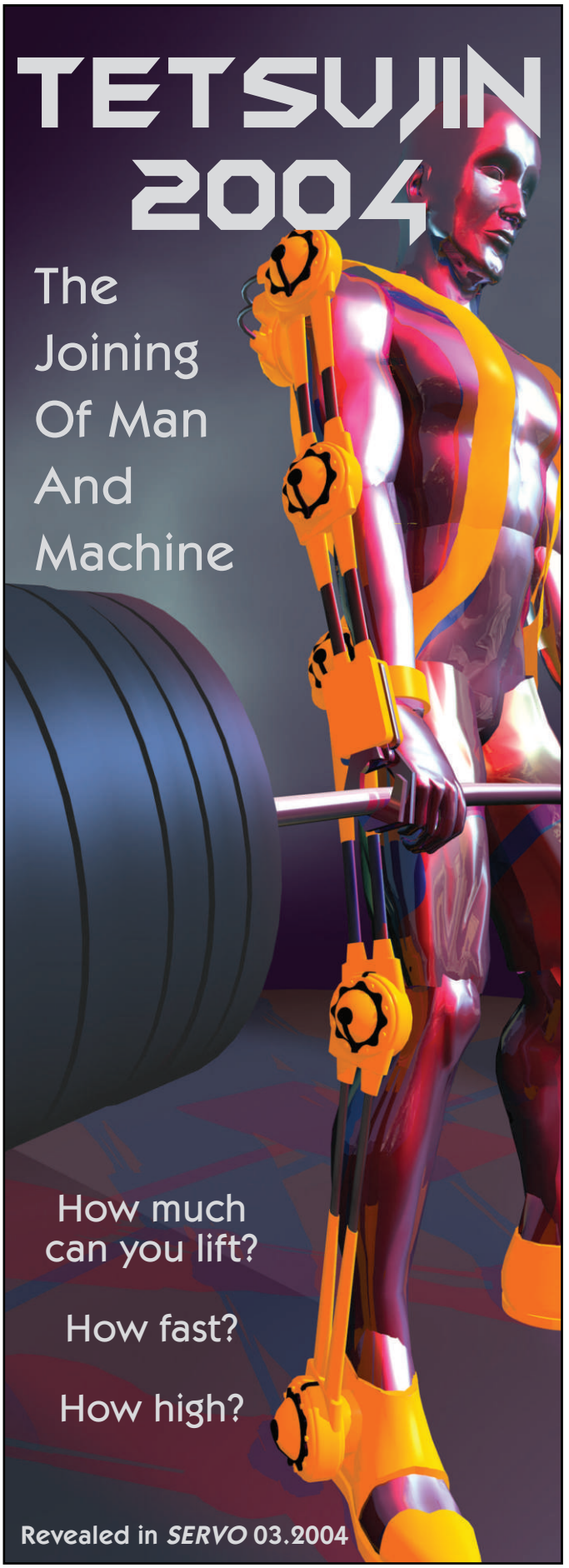
In addition to serving as RF repeaters, the smaller robots could also act as distributed motion-detecting sensors.

"For example," Everett says, "if your mission is to clear a building, and people run around and go back into parts of the building you've already inspected (when you're looking say, in one room, they sneak down the hall and go into the room you've looked into before), the robot can't see them while it's in this other room, but if they pass by some of these distributed sensors, they would detect the motion and alert the robot that somebody's moving, and come back and check it out."

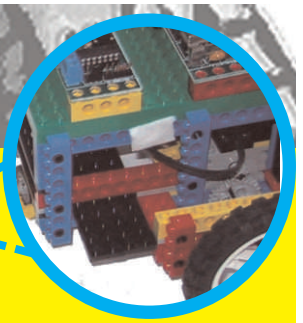
In *Gearheads: The Turbulent Rise of Robotic Sports* (Simon & Schuster, 2003), Newsweek author Brad Stone portrays Dean Kamen as being against the popular robotic warfare TV shows for pacifistic reasons. But he's remarkably sanguine about the battlefield applications of his invention. The AP story quotes Kamen as saying, "You build a car and it can either be used as an ambulance, or it can drive your troops around. My personal reason for liking (this program) is we would love to get more Segways at universities. The more we have our technology among the tech world, particularly the young geeks, it could only help us."

And hopefully save more than a few lives on the battlefield, as well. **SV**

Photos courtesy of the Space and Naval Warfare Systems Center — San Diego, CA



RoboBRiX Part 2



by William Benson and Wayne Gramlich

In last month's article, we discussed the concept behind the development of RoboBRiX™ and we looked at their technical specifications to see how they work.

This month, we will demonstrate how to use them to build a simple line-following robot. Even with a robot this simple, you will see that both the construction and programming are made easier with RoboBRiX.

Okay, we know we said in our last article that the primary reason for developing RoboBRiX was to make it easier to build robots more complicated than a simple line-follower. Then why are we messing around with this simple entry level robot design?

The answer is that a simple robot is a better choice to get you really familiar with how RoboBRiX work in practice. Once you understand the basics, it will be much easier for you to jump into the task of experimenting with more complicated and interesting robot designs, and in a future article, we will fulfill our promise and take on the challenge of building and programming a more interesting – and complicated – robot.

>>> CONSTRUCTION

Because we want to focus our attention on using RoboBRiX, we will cover the construction and assembly of our line-following robot only briefly, but hopefully, in enough detail that you will have a good idea about how everything fits together. The essential list of parts we need to build our robot includes: a platform, two motors, a **MicroBrain8** hub, a **DualMotor1Amp** function brick motor controller, and an **IREdge4** function brick for line detection.

Choosing the Platform

One of the nice features of RoboBRiX is that they are platform independent. We have, for example, constructed robots using LEGO® parts, Parallax's BoeBot and the Mondo-tronics RoverBase with OctoPanel (Figure 1), but they will also fit on most any other platform except those designed for very small or micro-size robots.

For our line-following robot platform, we decided to use the RoverBase with the OctoPanel add-on for the primary reason that this platform is specifically designed to accommodate the use of RoboBRiX. Furthermore, it comes with a Tamiya 70097 twin-motor gearbox, is quick and easy to assemble, and is readily available (as are the RoboBRiX described in this article) from **www.RobotStore.com** at a reasonable price.

Attaching Bricks to the RoverBase

On the RoverBase, we attached the **DualMotor1Amp** brick with 0.5 inch metal standoffs and sticky taped a quad AA battery pack that provided a separately dedicated power source for the motors. Next, we attached the motor leads directly to the **DualMotor1Amp** brick control ports and the six volt battery pack leads to the power terminal as shown in Figure 2.

Finally, using 2.5 inch metal standoffs, we attached the OctoPanel that held our **MicroBrain8**, **IREdge4** bricks and a nine volt battery to power our logic circuitry. In Figure 3, you can see the photo mask on the OctoPanel that suggests how to lay out up to six RoboBRiX on its surface.

OctoPanels can also be stacked vertically with the only limitation being when the addition of one more OctoPanel would make the robot top heavy and, therefore, unstable.

Attaching Bricks to the OctoPanel

The **MicroBrain8**, its nine volt supply, and the **IREdge4** complete the list of essential items used in our line-follower.

We attached the two bricks to the top of the OctoPanel using 0.5 inch metal standoffs and sticky taped the nine volt battery as shown.

Connecting the nine volt battery directly to the **MicroBrain8** brick supplied power and ground to all of the system bricks once we attached communications cables between the two function bricks and the **MicroBrain8** hub.

Arbitrarily, we connected the **DualMotor1Amp** brick to Socket 1, and the **IREdge4** brick to Socket 2 of the **MicroBrain8** with our standard four line flat wire cables (see Figure 4).

The Line Sensors

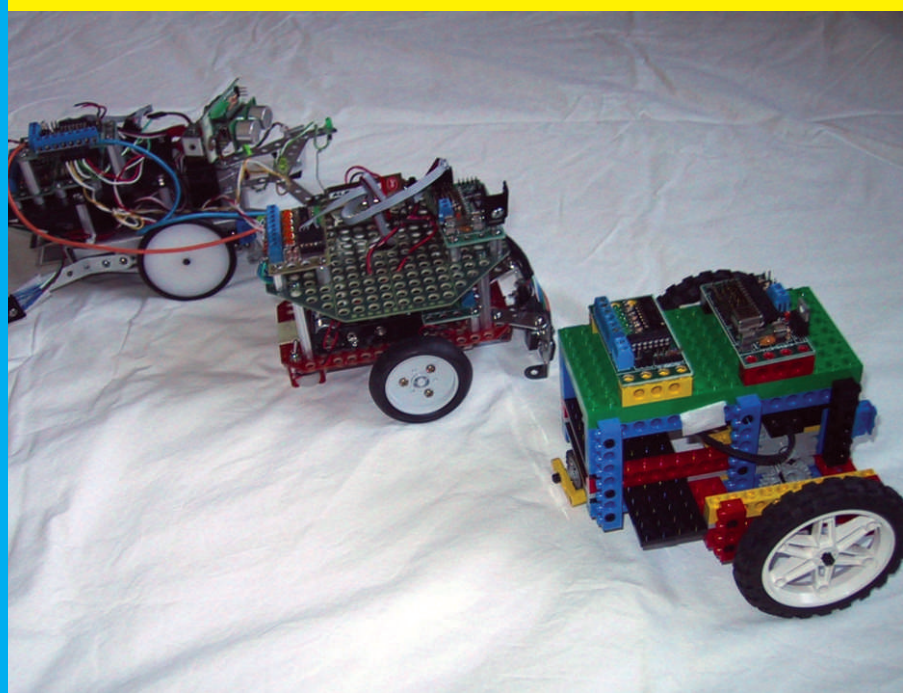
For this project, we decided to use the Fairchild Phototransistor Reflective Object Sensors (QRB1134) for our line tracking sensors (Figure 5). The QRB1134s come with hookup wires attached and they have a slot in the middle that makes for easy vertical alignment of the sensors above the course surface. Each sensor contains an LED and an IR sensor physically arranged so that the LED will reflect directly into the IR sensor when a reflective surface is approximately 4 mm away.

The short range nature of the QRB1134 makes it ideal for line-following applications. Also, the sensors directly connect to our **IREdge4** brick without any additional support circuitry.

Mounting and Connecting the Line Sensors

We mounted the four QRB1134 sensors to the front of

Figure 1. **RoboBRiX on a BoeBot, RoverBot, and LEGO Bot.**



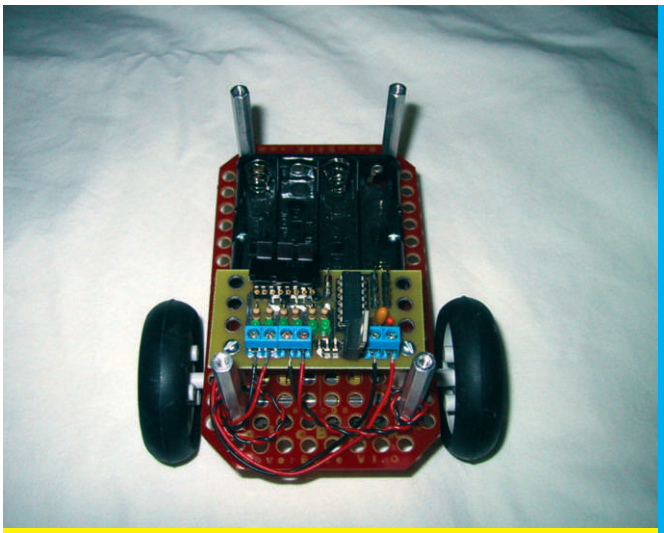
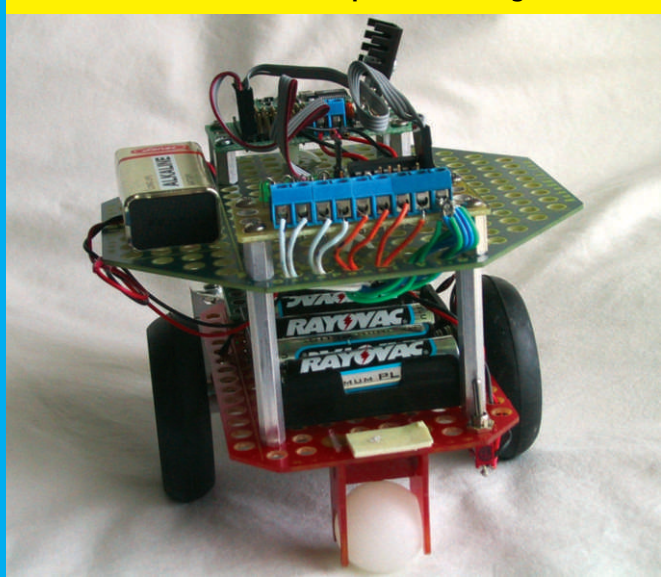


Figure 2. **The RoverBot base with DualMotor1Amp attached.**

the RoverBase chassis as shown in Figure 6. This arrangement placed all of the sensor's LEDs and detectors along a single line perpendicular to the robot's forward path so that, at most, two sensors could track a 0.75 inch wide black line (we used plastic electrical tape) at any one time.

This is not an optimal orientation, we admit, but it served our purposes well enough. The four QRB1134 sensors connect directly to the **IREdge4** brick: the blue and green ground leads are connected together for all four sensors at Terminal G, the orange leads are the IR LEDs and connect respectively to Terminals Led0, Led1, Led2, and Led3. And finally, the white leads are the IR detectors and connect respectively to the remaining Terminals In1, In2, In3, and In4 (Figure 4).

Figure 4. **Socket connections and the QRB1134 hooked up to the IREdge4.**



>>> FUNCTION BRICK DETAILS

DualMotor1Amp - Dual Motor Controller

Since the RoverBase uses the Tamiya gearbox and DC motors to provide both locomotion and differential steering, we chose the **DualMotor1Amp** brick as our dual motor controller. This brick can independently control the speed and direction of up to two small DC motors, but it also offers the user a number of other options that can add considerable refinement to motor control operations:

• **Ramping** — Ramping is the gradual acceleration of the motor from its present motor speed state to the desired motor speed state by incrementing or decrementing the speed in small steps over time. Gently altering the speed instead of changing it in one immediate step is easier on the motors and batteries (it often looks smoother, too).

• **Power Mode** — The two different power mode settings available are: pulsed power and continuous power. Pulsed power is just another name for pulse width modulation (PWM), where the motor is "on" for part of the duty cycle period and "off" for the remainder.

In the continuous power mode, the motor is on 100% of the time but it runs in the forward direction for a part of the duty cycle and in the reverse direction for the remainder of the duty cycle. The user might prefer this mode to achieve better speed control at very slow speeds.

• **Pre-scaling** — The duty cycle can affect how acoustically noisy the motor will be in operation. Sometimes, it is best to just try a few different duty cycle periods to find the one that is the quietest. To provide for this, eight discrete duty cycle periods are available for selection by the user: 0.5, 1, 2, 4, 8 16, 32, and 64 µS. The default duty cycle period is 0.5 µS.

• **Failsafe** — This mode is included as a safety feature that, when enabled, will shutdown the robot's motors in the event of a top level program failure.

This is a welcome feature because no one wants to see their robot go on an uncontrolled rampage, crashing into anything in its path until it has either destroyed itself or finally stopped due to a dead battery.

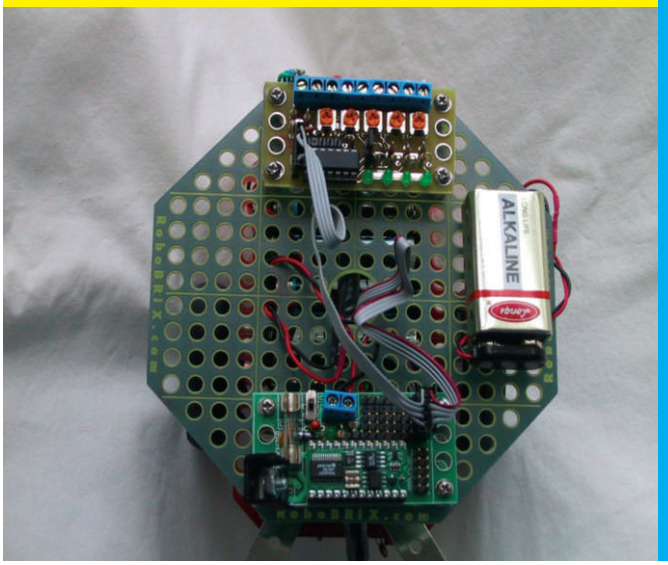
IREdge4 - Line Tracker

The **IREdge4** brick was designed to continuously read the analog outputs of up to four individual, unmodulated IR sensors and automatically convert their readings into an equivalent eight bit digital value that is useable by the

brick's microprocessor. The four resulting eight bit digital equivalent values are stored in separate registers that are accessible directly by the user. Since there are occasions when we might prefer to read out the equivalent digital value as a 1 or a 0 bit instead of a byte, we can set a high and a low threshold value to represent the points above and below which the equivalent value should be expressed as a 1 or a 0 respectively. The user can create a hysteresis effect in the readings by setting the high and low thresholds to different values or he can eliminate the effect of hysteresis altogether by setting them both to the same value.

The QRB1134 is an active low device. This means it will produce a voltage near zero when over a highly reflective surface and a voltage near 5 V when over a non-reflective surface. A sensor's active high or active low characteristic is not always the preferred choice for a particular application, so we designed the **IREdge4** brick with a complement feature that allows the user to convert the output of a sensor from active low to active high or vice versa whenever needed. Finally, the **IREdge4** brick has a dedicated potentiometer and LED for each sensor so that the user can adjust and observe the sensitivity of it independently. This is an important feature that permits the user to ideally balance the array of sensors so that they respond identically to a given situation. If there is a change in the ambient lighting environment after the user has balanced the individual sensors, he can adjust the sensitivity of the group as a whole, using the global potentiometer provided on the fly and without having to do any reprogramming.

Figure 3.
Top view of OctoPanel.



Implementation

Which of the many attributes of these bricks should we use? Well, for the **DualMotor1Amp** brick, we used the pulsed power mode and the default duty cycle period of 0.5 µS, but without ramping or failsafe protection. For the **IREdge4** brick, we wanted our sensor data in bit form so that we could get the status of all four sensors with a single reading. To do this, we accepted the default high threshold and low threshold values set at 0xC0 to get our bit data without any hysteresis effects. In addition, since the sensor is supposed to track a dark line, not a white one, we used the **IREdge4** brick's complement mask to change the output so that it will produce a 1 when the sensor is over the black line and a 0 when it is not. The four LEDs assigned to the sensors will always give us a visual confirmation that our set-up is working properly.

State Chart

State*	Means	Action
0000	line is lost	stop to avoid disaster
0001	line is far to the right	steer hard left
0011	line is close on the right	steer gently left
0110	tracking center of line	continue forward
1100	line is close on the left	steer gently right
1000	line is far to the left	steer hard right

* ('0' = sensor off; '1' = sensor on)

>>> LINE FOLLOWING ALGORITHM

The way we have physically arranged the sensors limits — to a maximum of two — the number of sensors that can track the line at the same time. Therefore, we have only six possible sensor states to show us the status of the line's position relative to the robot and, consequently, we need to pick only one command out of six possible choices to give appropriate directions to the motors:

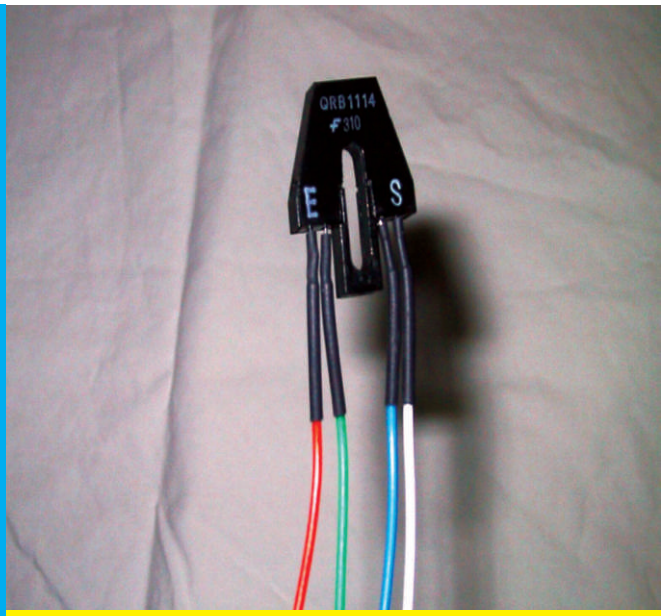


Figure 5. Fairchild PhotoTransistor Reflective Object Sensor (QRB1134).

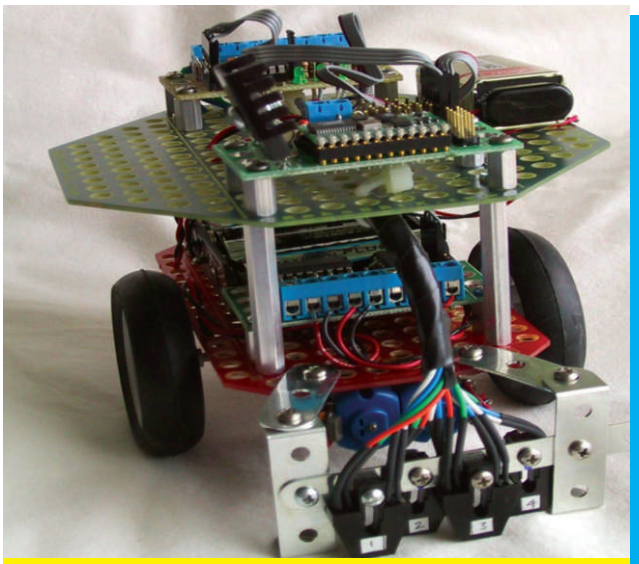


Figure 6. Socket Connections and QRB1134 Hookup to IREdge4.

Circle #74 on the Reader Service Card.

Command	Send/Receive	Byte Value 7	6	5	4	3	2	1	0	Definition
Read Pin	Send	*0*	*0*	*0*	*0*	*0*	*0*	*b*	*b*	Read pin *bb* and respond with 8-bit value *vvvvvvvv*
	Receive	*v*	*v*	*v*	*v*	*v*	*v*	*v*	*v*	
Read Binary Values	Send	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	Return the binary values *abcd* (after XOR'ing with complement mask)
	Receive	*0*	*0*	*0*	*0*	*a*	*b*	*c*	*d*	
Read Raw Binary	Send	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*1*	Return the raw binary values *abcd* (no XOR with complement mask)

Table 1. Exerpt from the IREdge4 Programming Chart.

Command	Send/Receive	Byte Value 7	6	5	4	3	2	1	0	Definition
Quick Set	Send	*0*	*0*	*h*	*h*	*h*	*h*	*d*	*m*	Set motor *m* speed to *hhhh hhhh* and direction to (0=forward, 1=backward)...
Set Low	Send	*0*	*1*	*l*	*l*	*l*	*l*	*d*	*m*	Set low order 4 bits of motor *m* speed to *ll* and direction to *d* (0=forward, 1=backward).
Set Ramp	Send	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*m*	Set the ramp for motor *m* to *rrrrrrrr* (00000000=no ramp (default))
	Send	*r*	*r*	*r*	*r*	*r*	*r*	*r*	*r*	
Set Failsafe	Send	*1*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	Set the failsafe delay variable to *ffffffff* (00000000=off (default))
	Send	*f*	*f*	*f*	*f*	*f*	*f*	*f*	*f*	

Table 2. Exerpt from the DualMotor1Amp Programming Chart.

Writing the Top Level Code

Now that we have a mobile robot platform and some appreciation for the capabilities of the RoboBRiX we have chosen, let's review the top level program in Listing 1. This is the program the user writes to animate the robot's behavior as a line-follower and it gets downloaded to the Stamp BS2 on the **MicroBrain8** hub brick.

We chose the popular Parallax BASIC Stamp BS2 as our microprocessor for the **MicroBrain8** and wrote the program in PBasic 2.5 using the Parallax Stamp Editor/Development System Ver. 2.0 Beta 2.1. The PBasic version has some very useful new software commands and the addition of color makes reading the program much easier.

All comments appear in green, program directives in magenta, program commands in blue and all other text in black. Note that the program listing is too lengthy to be included here, so please visit the *SERVO Magazine* website (**www.servomagazine.com**) to download a copy.

Command Byte		Motor Response		
HEX	BINARY	SPEED	SELECT	DIRECTION
0x00	0000 0000	0x00 (Halt)	Left	Forward
0x01	0000 0001	0x00 (Halt)	Right	Forward
0x20	0010 1000	0x88 (Slow)	Left	Forward
0x21	0010 1001	0x88 (Slow)	Right	Forward
0x3C	0011 1100	0xFF (Fast)	Left	Forward
0x3D	0011 1101	0xFF (Fast)	Right	Forward

Table 3. DualMotor1Amp "Quick Set" Command Bytes.

Program Flow

The program order begins with constant declarations followed by variable declarations, initialization of variables and start conditions, main program code, and ends with a single subprocedure. The comments included should be

sufficient to explain the use of the various constants and variables. In the Initialization section, you should note that we used the HIGH command to set the Brain's output lines to each of the two function bricks.

We found that this was a necessary pre-condition to insure the start of reliable serial communication between the Hub and the function bricks.

Main Program Loop

The main program continuously executes two specific operations in an endless DO-LOOP. The first operation reads the current sensor data from the **IREdge4** brick and the second operation sends the appropriate response command to the motors via the **DualMotor1Amp** brick. How do we read the current sensor data from the **IREdge4**? Well, first we consult the **IREdge4** programming table (Table 1) and look for a command that will instruct the brick to return the desired information. The Read Binary Values command appears to be exactly what we need. It tells us that if we send the **IREdge4** a command byte equal to 0x04, it will send back the current bit values of each sensor in the format 0000abcd. We know that the nibble abcd will be one of the six states shown in the state chart above. Once the nibble abcd is known, the proper motor response is decided by filtering the value through a series of case statements until the matching case is found. The left and right motor speed variables take on the successful case values that use appropriate commands shown in Table 3. The final program step is a call to the Motor_Control subroutine that sends this information to the **DualMotor1Amp** brick using the Quick Set command described in its programming table (Table 2). At this point, our robot is complete so it's time to download the program to the BS2 on the **MicroBrain8** and watch the robot follow the black line.

Conclusion

What did we learn from this exercise? Well, among other things, we learned how easy it is to send instructions to a brick or get information back from one, and while neither the QRB1134s nor the DC motors require any critical timing loops, if they did, it would not force us to change the code we wrote. Finally, we didn't have to design and build any circuitry to control the motors or to use the QRB1134 sensors. Instead, we just plugged them directly into their respective RoboBRiX. In our next RoboBRiX article, we will introduce the **IRProximity2** and **Servo4** bricks and show how to use them to build a wall-following/object-avoiding robot. SV

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Bender

Bob Allen, Ben Lomond, CA

Bender is a 24-inch-high two-wheel, self-balancing robot that is controlled by two PIC microcontrollers, a gyroscope, and a tilt sensor. It is powered by a 24-volt battery for the motors and a separate 12-volt battery for the electronics. It will balance for up to five hours on a full charge.

Bender took Ted Larson and Bob Allen over seven months to design and build. Bender and ISIS, Bender's twin brother, both made their debut at Seattle's Robothon this year.

www.tedlarson.com
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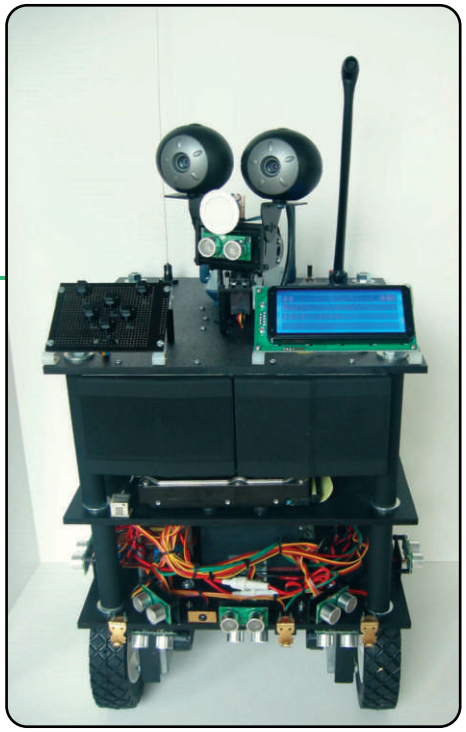

Open Automaton Robot

A team of hundreds, Worldwide

The aim of the Open Automaton Project is to develop a generic design for an affordable, PC-based mobile robot suitable for navigating autonomously around home or office environments, according to Dafydd Walters, the project leader.

This prototype droid, built by Walters to prove the design, was on display at the Seattle Robotics Society 2003 Robothon in Seattle, WA, and picked up the Judges' Choice award. At the heart of the prototype is the 1 GHz EPIA M 10000 mainboard from VIA, which has proved to be a hit in robotics circles, also finding its way into the Linux-based Centibots that were on display at LinuxWorld 2003.

The robot boasts an impressive array of sensors, including sonar, vision, infrared (tuned to the human body's infrared emissivity), and wheel encoders for odometry. To keep the project within the financial reach of hobbyists, costs are minimized by using readily available "off-the-shelf" consumer-grade hardware components.The prototype droid costs less than $2,000.00 to build.

http://oap.sourceforge.net

Robytes

by Dave Calkins

Robots to the Rescue!

Almost two years ago, the oil tanker, *Prestige,* split in half and sunk off the coast of Spain. 77,000 tons of oil were spilled into the coastal waters when it sank and the beaches and local critters are all now as covered in oil as you are each time you try to change those hydraulic lines (I TOLD you to drain them first). Underwater robots will travel two and a half miles to the ship's remains, cut holes in the tanker, fit the holes with valves, and suck out the remaining 13,000 tons of oil. The oil will be caught by aluminum shuttles which will return to within 40 feet of the surface for the oil's transfer via pipe to a surface ship. The Spanish oil firm Repsol will manage the recovery of the oil.

Greenpeace is undoubtedly at a loss as to whether to cheer the cleanup or jeer the proliferation of robots ...

Rename it VROOM-ba!

Photo courtesy of iRobot Corp

In the "preaching to the choir" file: You will be shocked — SHOCKED! — to learn that iRobot cannot keep Roomba on the shelves. Sales have increased 600 percent since the newer models hit store shelves. Mind you, it probably doesn't hurt that their website has a selfless "permission slip" which lets users print up a request to their loved ones asking for the vacuum as a gift. But when it comes down to it (and in Roomba's case, it really gets down to it), this is the first practical in-home robot. Pool cleaning robots have been around forever, but they don't have to deal with differentiating between carpet patterns and baby's first vomit patch — much less navigating around lethargic cats. But Roomba's success does herald in the true beginning of the age of the home robot.

Alrighty then my clever readers. Remember the three most important letters when writing your business plan: "R.O.I." And don't forget that 20% of your fifth year's gross revenue goes to your favorite robot columnist.

Bad Robot! You Think Too Much!

Those crazy Swedes! A researcher at the Royal Institute of Technology in Stockholm, Philipp Althaus, thinks that dumbing down robots is the way to go. Working at the Center for Autonomous Systems, he thinks that dumber robots make better robots. Since most household robots take up inordinate amounts of CPU time just trying to map the room in which they're working, the way to make them faster is to make them more efficient. If a robot encounters a cat moving around the room, it might think that it's a fixed object, and keep blocking off parts of the room until not much is left — as it's all occupied by the same cat. The more often the cat moves, the slower the robot gets trying to figure out which areas of the room are free and which are open. So, killing short term memory for robots might make them much more efficient.

Dude, pass the chips — my robot's got the munchies.

Run, Robot! Run!

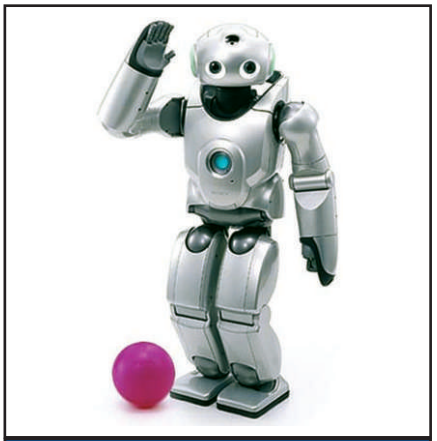

Photo courtesy of Sony Corp

Baby's first step was but a few years ago with Honda's P3. Real live walking robots. Okay, they couldn't do the meringue as well as Nana, but hey — it's a long way from a guy in a rubber suit with a bunch of aluminum foil wrapped around his face. Then came the Asimo, Fujitsu's HOAP, and Sony's SDR (now Qrio). All very similar in concept. But they still only moved about as fast as grandma on an extra dose of Metamucil. Well, Sony has now crossed a significant barrier. Jogging. Sure, any three-year-old can do it, but three-year-olds have eons of evolution going for them. Sony's latest Qrio is capable of actually running. This means both feet being off the ground at the same time. If Neal Armstrong was a giant leap for mankind, this is a huge jump for robo-kind.

One of the major problems in robot locomotion has been true bipedal movement – would you rather have R2-D2 in your home or C-3PO? Wheels are easy, but limited to two dimensions. True bipeds can run and go up stairs. With some more improvements in balance and forward thrust, in a few years we can look forward to Rosie, robot soldiers, and robot waiters!!! Just think of all the money you'll save on tipping!

Of course, with all those robot waiters, aspiring actors may have to

find jobs as robot technicians.

Danger B9! You are About to be Replaced!

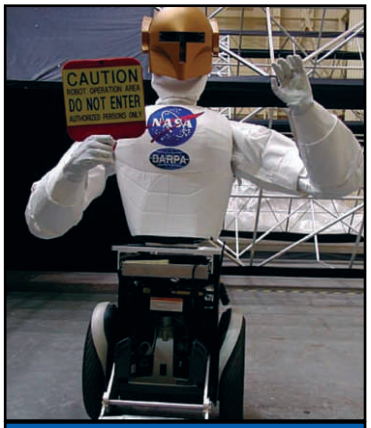

Photo courtesy of NASA

Everyone reading this article knows B9, the robot from *Lost in Space* (No, his name was not Robby the Robot — that was *Forbidden Planet*.) Well, the Robot Systems Technology Branch at NASA's Johnson Space Center is diligently working to make a real life B9 to help future astronauts (who will presumably not be named Robinson). The goal is to build a robot that can operate outside of the shuttle or the International Space Station. Unlike most specialized robots, the goal of "Robonaut" is to closely replicate the upper torso and hands of a human. Robonaut's hands have four fingers and a thumb, much like us, except robonauts won't need oxygen, so they can operate without the limits put on us mere mortals. Eventually, they'll be able to work in space, while the astronauts tele-operate them from a safer environment (such as their living rooms — while watching the Niners lose once again). Being able to grab any tool as we would, the robots will become a cost effective augmentation to the space program. But it kinda takes the fun out of being an astronaut, if you want my opinion ...

And you Thought 7of9 was Hot ...

Photo courtesy of the Ministry of Foreign Affairs of Japan

She's Asian, she's hot, and she's worth millions. She's got full diplomatic immunity, works for the Ministry of Foreign Affairs, has been seen in most countries of Asia, and speaks multiple languages. She's the goodwill ambassador of Japan for the ASEAN (Association of Southeast Asian Nations) — Japan Exchange 2003. Her name is as mellifluous as you could ever hope for: Sakura Sanae. Her first name, Sakura, is Japanese for "cherry blossom". Her face adorns posters in Japan, Malaysia, Indonesia, Laos, Vietnam, and three other countries. The first day her position was announced in Japan, the server load to her homepage had so many requests that the Ministry of Foreign Affairs web server crashed. And yet, through all of this, there is still hope: she doesn't have a boyfriend. She might be a little too diplomatic for you — I can't envision her chugging brewskies and discussing the finer points of Quake, but still — she adores computer programmers. Oh. I forgot. She's an AI CGI robot. Her last name, "Sanae" is an anagram of ASEAN. I guess you'll have to stick with match.com SV

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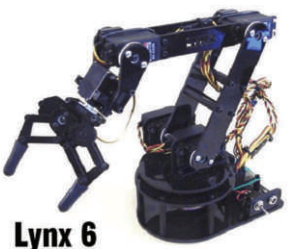

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Mind Candy For Today's Roboticist

Building Robot Drive Trains
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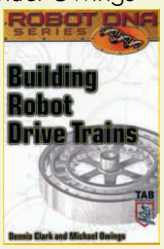

This essential title in McGraw-Hill's *Robot DNA Series* is just what robotics hobbyists need to build an effective drive train using inexpensive, off-the-shelf parts. Leaving heavy-duty "tech speak" behind, the authors focus on the actual concepts and applications necessary to build — and understand — these critical force-conveying systems. **$24.95**

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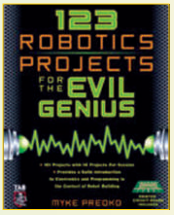

If you enjoy tinkering in your workshop and have a fascination for robotics, you'll have hours of fun working through the 123 experiments found in this innovative project book. More than just an enjoyable way to spend time, these exciting experiments also provide a solid grounding in robotics, electronics, and programming. Each experiment builds on the skills acquired in those before it, so you develop a hands-on, nuts-and-bolts understanding of robotics – from the ground up. **$25.00**

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Amphibionics
by Karl Williams

This work provides the hobbyist with the detailed mechanical, electronic, and PIC microcontroller knowledge needed to build and program snake, frog, turtle, and alligator robots. It focuses on the construction of each robot in detail, and then explores the world of slithering, jumping, swimming, and walking robots, and the artificial intelligence needed with these platforms. **$19.95**

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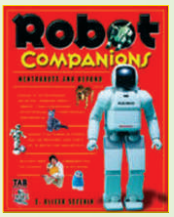

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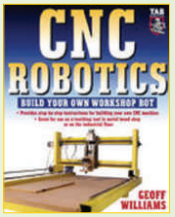
CNC Robotics
by Geoff Williams



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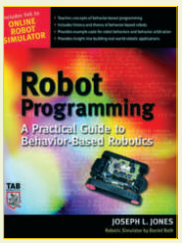
by Chris Hannold

Packed with informative illustrations, *Combat Robot Weapons* also expands on fighting strategies for each weapon type to further solidify your understanding. The enclosed CD-ROM contains spinner weapon plans, robot combat videos, software, and more to help you turn your robot into a battle-ready metal warrior. **$24.95**

Robot Programming
by Joe Jones / Daniel Roth



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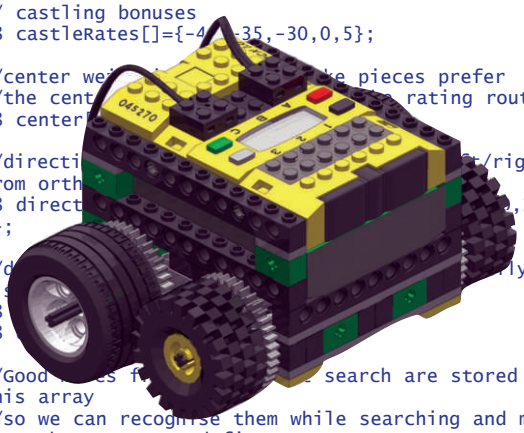


A NEW bi-monthly column just for kids!

LESSONS FROM THE LABORATORY

— PART 1 —
Building Eddie

by James Isom

After several years of teaching robotics to elementary and middle school students, there isn't any doubt in my mind that robotics is a powerful hands-on method of teaching science in a meaningful way to students. This column is devoted to exploring those applications and the world that makes up student robotics. We start this month by building a robot using the LEGO Mindstorms system. As time progresses, we will explore other systems, student competitions, design challenge ideas, and cool robot hacks to excite and inspire you.

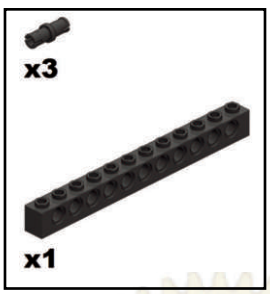
This month, we build "Eddie" which I will use in subsequent months to teach a variety of Mindstorm basics. If you are an experienced LEGO roboticist, the upcoming articles will be a good review of the basics. For those of you who are just starting or just have had a Mindstorms kit lingering in the closet and don't know what to do with it, then these articles are for you. Pull out your kit, dust it off, and let's get building!

The instructions below highlight the parts to be added in each step. Parts assembled in previous steps are turned white to clearly delineate the new parts being added. This model can be built from a single Robotics Invention System (RIS) 2.0 (set# 3804) or Team Challenge Set (set# 9794). For more information on how to measure LEGO parts or the difference between a plate and a beam, please consult the booklet that came with your set or visit my website at **www.theroboticslab.com**

STEP 1:

Place the black friction pins in the fourth, sixth, and eighth holes of the 1x12 beam.

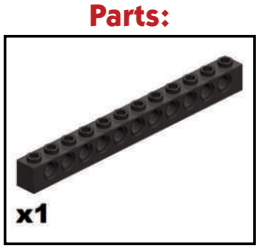
Parts:



STEP 2:

Slide the 1x12 beam on the friction pins.

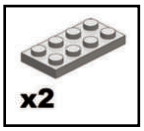
Parts:



STEP 3:

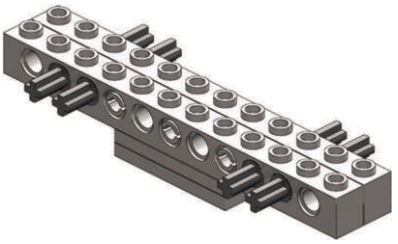
Stack the two 2x4 plates on top of one another and attach them to the bottom middle of the beams.

Parts:



STEP 4:

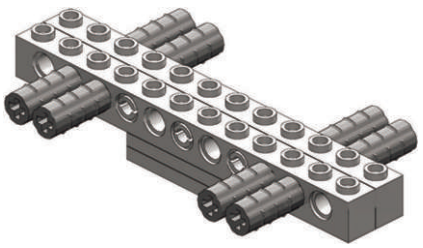
Starting from each end of the beam, place axle pins in the second and third holes on either side of both beams.



Parts:

STEP 5:

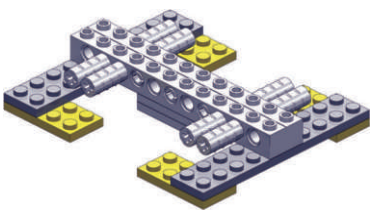
Place an axle joiner on each axle pin.



Parts:

STEP 6:

Attach a 2x4 plate to each end of a 1x12 plate. Fix the 1x12 plate underneath the beam on the chassis. This will hold your motor mounts to the chassis structure.



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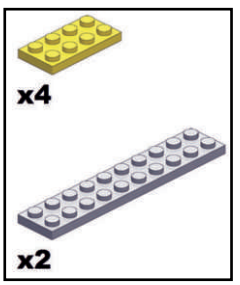
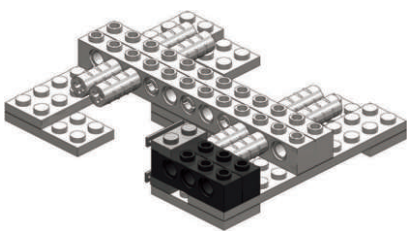


STEP 7:

Build a motor mount by placing two 1x4 beams between the 1x2 plates with the rails facing inside.



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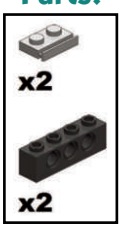
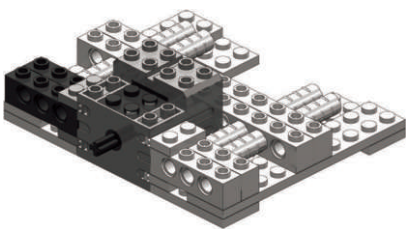


STEP 8:

Finish the motor assembly by repeating step 7. Place the four rails in the slots on either side of the motor. It will be easier if you build this motor assembly and then attach it to the chassis.



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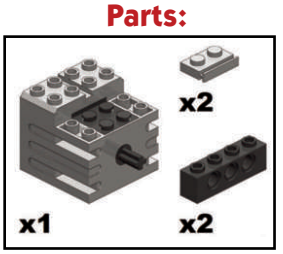
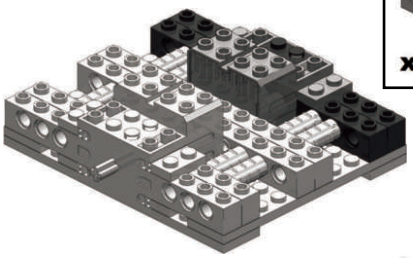


STEP 9:

Build another motor assembly for the other side.



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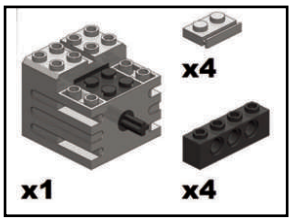
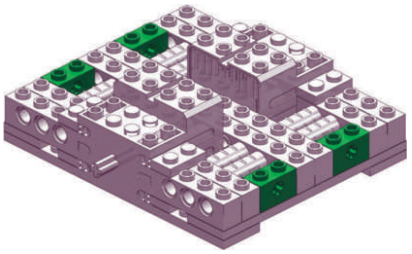


STEP 10:

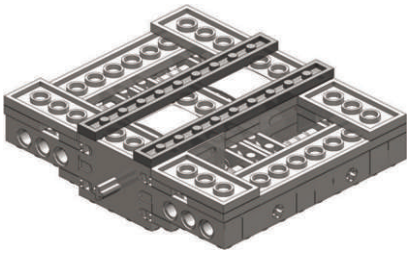
Place a 1x2 brick with axle hole in the two stud spaces between each motor mount and the main chassis beams.



Parts:

STEP 11:

For additional strength, flip the chassis over and add a 1x10 plate on either side of the belly of the motor.



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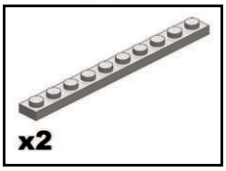
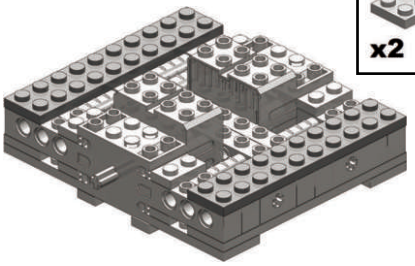


STEP 12:

Flip the chassis back over and add a 2x10 plate across each end of the chassis.



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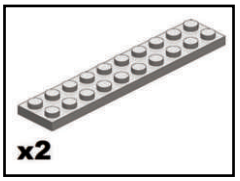
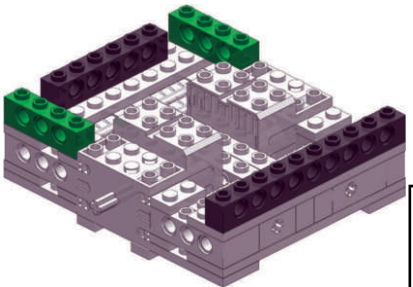


STEP 13:

Add the beams in the configuration shown.



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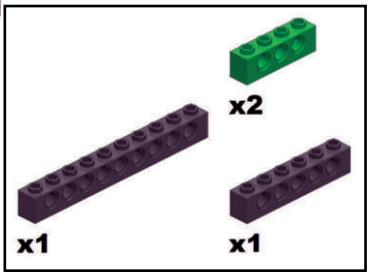
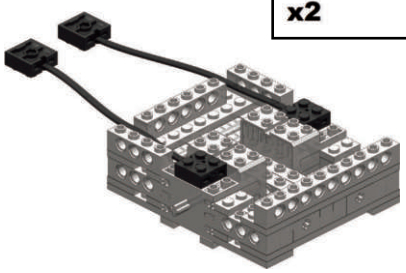


STEP 14:

Attach two short wires to each motor. Thread the rest of the wire through the two slots left vacant between the beams from the previous step.



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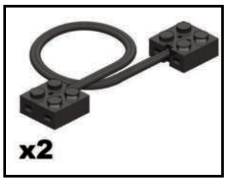
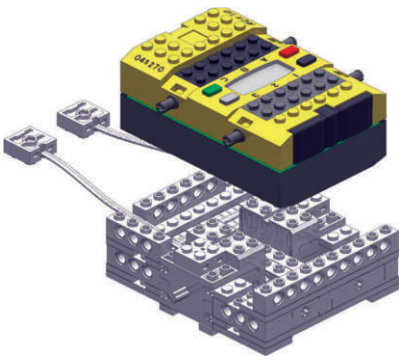


STEP 15:

Insert four 3/4 pins (short side towards the RCX) in each hole of the RCX. Do not attach it to the chassis at this time.



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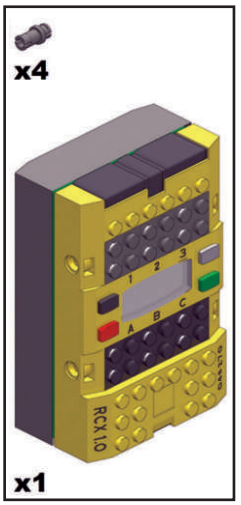
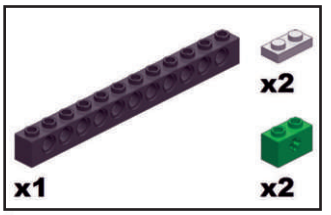
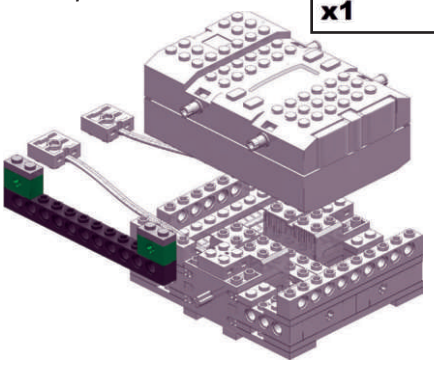


STEP 16:

On a 1x12 beam, place two 1x2 bricks with axle holes on each end. On top of the bricks, place a 1x2 plate.

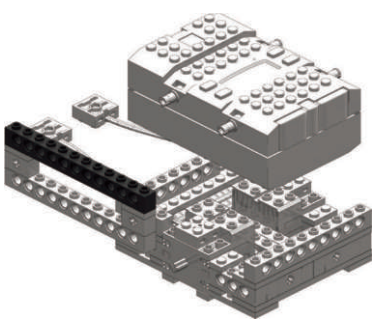
Parts:





STEP 17:

Place a 1x12 beam on top of the two 1x2 plates and attach this to the 3/4 pins on the RCX. The two short edges should be flush with the front and back of the RCX.



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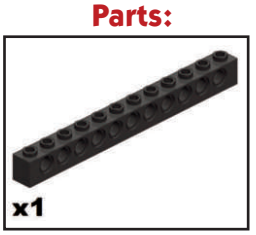
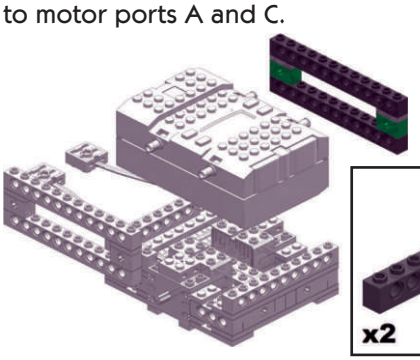


STEP 18:

Repeat steps 16 and 17 and attach another side structure to the other side of the RCX. Once both sides are attached, place the RCX and its two new sides to the top of the chassis. Attach the two wires to motor ports A and C.



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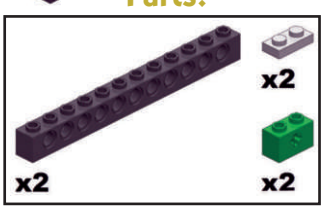
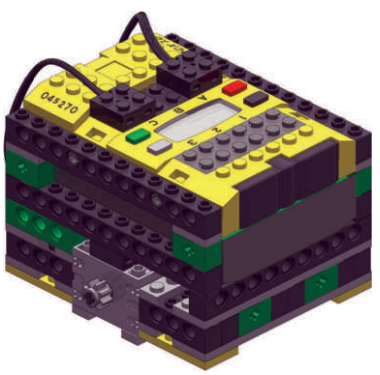


STEP 19:

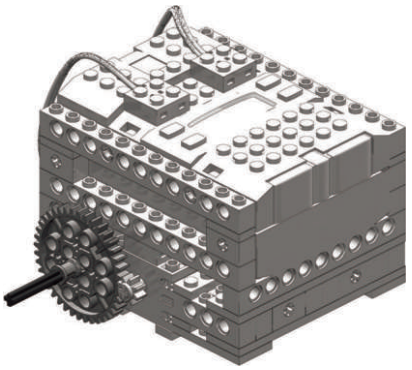
Place an 8-tooth spur gear (commonly referred to as an 8T gear) on each motor shaft.



Parts:

STEP 20:

Insert an 8-axle (an 8-axle is eight studs long) in the hole closest to the motor on the rear motor mount. Place a 40 tooth spur gear (40T) on the axle followed by a bushing. The bushing is there to not only keep the gear from drifting, but also to provide just enough space to keep the tire from rubbing on the 8-tooth gear.



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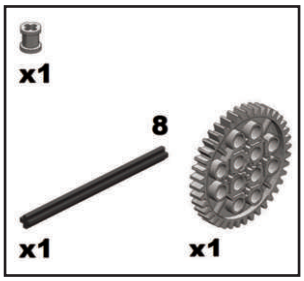
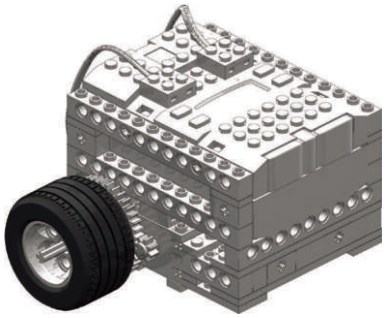


STEP 21:

Slide a tire and wheel hub on the axle. Make sure the raised center of the wheel hub is on the inside facing the bushing.



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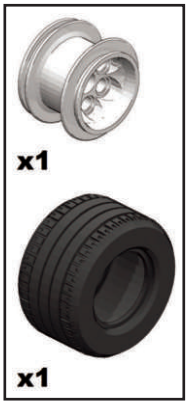
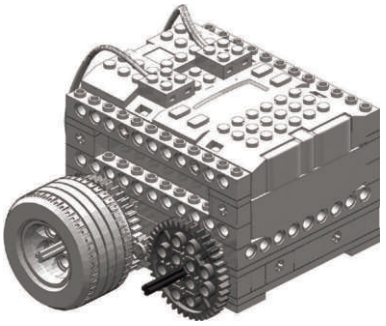


STEP 22:

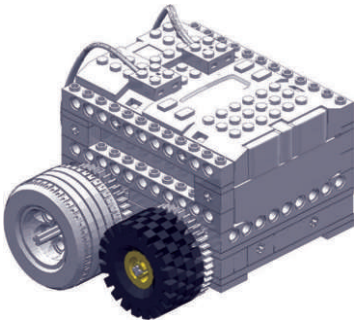
Insert an 6-axle (six studs long) in the hole closest to motor on the front motor mount. Place a 40 tooth spur gear (40T) on the axle, but don't follow it with a bushing this time. The tires we are using in the front are slightly smaller and won't run against the gear.



Parts:

STEP 23:

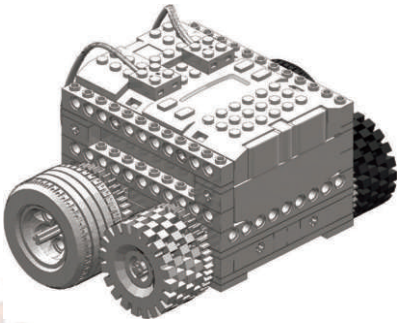
Place two tires on the axle. Make sure the side of the tire with the indentation is facing out. For those of you with RIS 2.0 systems, you might only have two of these tires. I prefer four for only aesthetic purposes; two tires will work fine for our purposes.



Parts:

STEP 24:

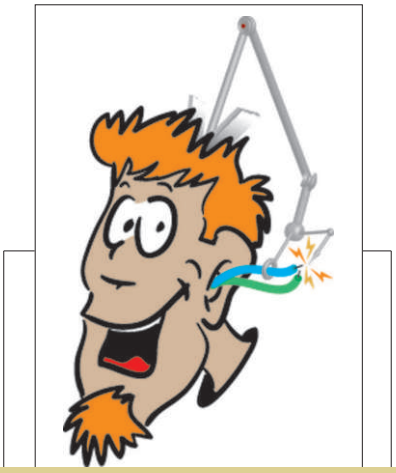
Repeat steps 22 and 23 to add wheels to the other side.



STEP 25:

You're finished! Congratulations!

Next time, we'll start to explore sensors and some basic programming techniques. Stay tuned. **SV**



AUTHOR BIO

James Isom is a part-time robotics teacher and general all-around geek. He has taught robotics to children and teachers in the US and abroad. His website with other additional goodies (including the MLCAD file of this robot) can be found at **www.theroboticslab.com** He can be reached at james@megagiant.com

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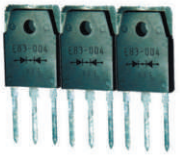

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Hadamard Transform Based Neural Net

by Sean O'Connor

Traditional neural nets often require extensive training, impose a heavy computational burden, or are maladapted to implementation on resource-limited devices such as microcontrollers.

An alternative neural net topology based around the Hadamard transform addresses many of these problems and should be readily applicable to system control applications. Particularly attractive is the good numerical stability and reliable behavior that can be obtained.

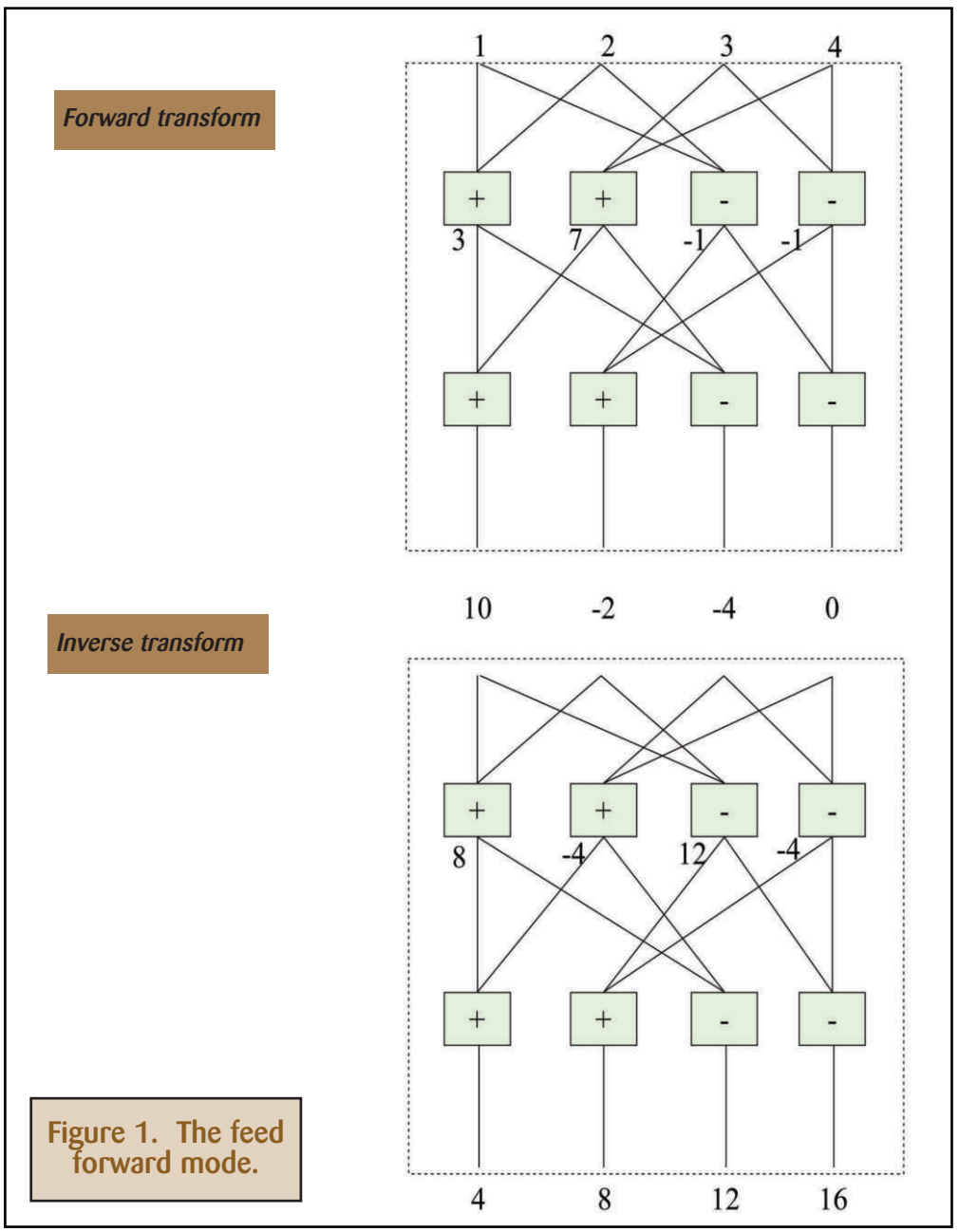

Figure 1. The feed forward mode.

The Hadamard Transform

If you are given the sum (a+b) and difference (a-b) of two numbers, you can find the original numbers by forming the sum and difference again and then dividing by 2 (i.e., a=((a+b)+(a-b))/2 and b=((a+b)-(a-b))/2).

A more symmetrical situation would be where you are given x=(a+b)/v2 and y=(a-b)/v2; in which case, a=(x+y)/v2 and b=(x-y) /v2. Effectively, x and y are the Hadamard transform of a and b that you then transform again to get back the original values.

Figure 1 shows how to extend the transform to four points using two calculation steps, in general for n=2^k (k integer>0) data elements, you take the data through k steps to do the transform.

Obviously, any time you take your data through 2k steps you get your original data back, since the forward and inverse transforms are the same (with division by

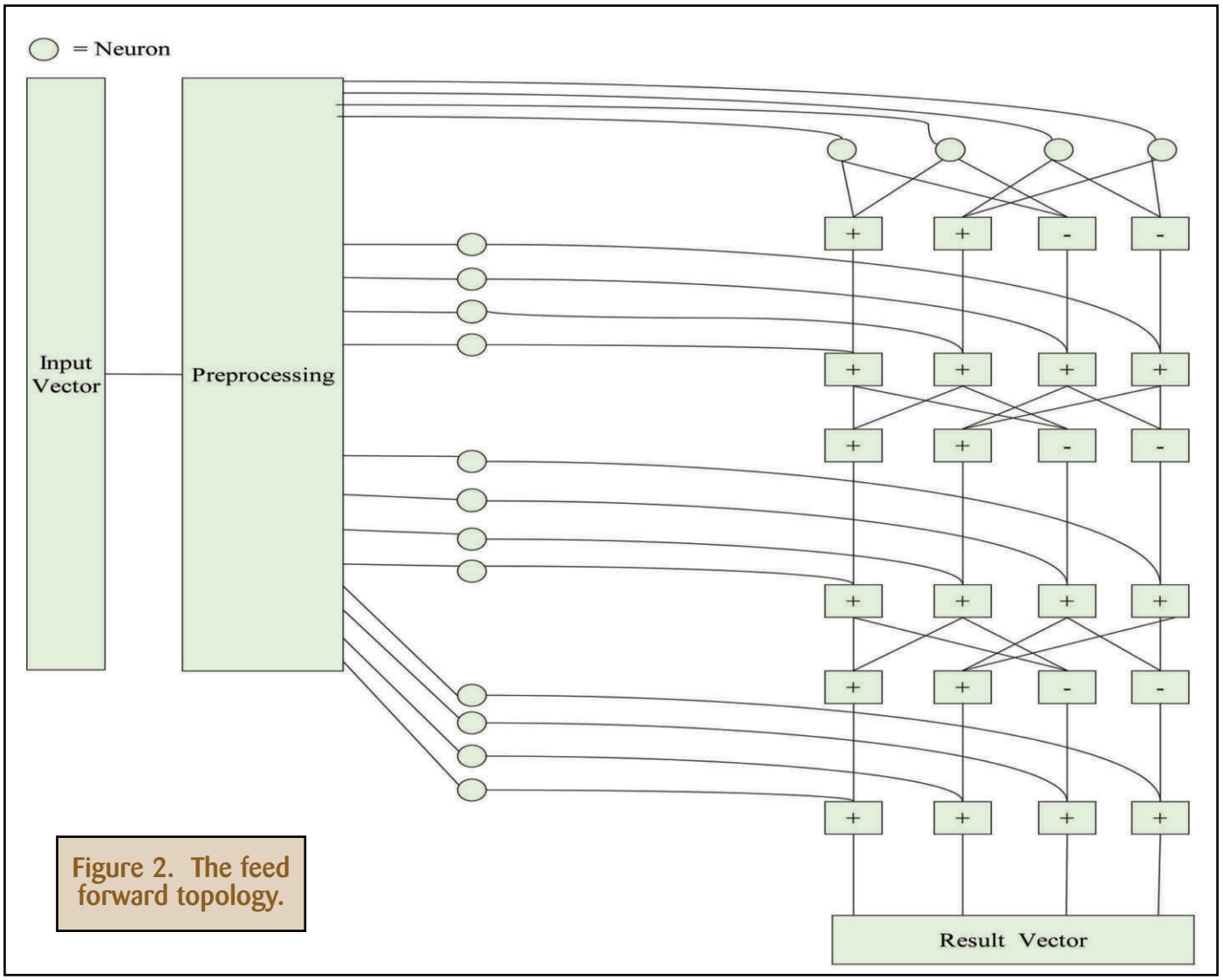

Figure 2. The feed forward topology.

the appropriate scaling constant at the end if you don't divide by the square root of two at each addition and subtraction).

The Feed Forward Mode

The idea here is to perform 2k-1 **HTStep** function calls (see Table 1), adding in a vector formed from outputs of a layer of neurons (which are responding to some specific input) at each stage.

We first obtain an initial vector from the first layer of neurons. We apply the **HTStep** function to that vector and then add in outputs of our next layer of neurons and so on till we have gone through 2k-1 **HTStep** function calls and used the outputs of 2k(2^k) neurons (i.e., 2k neuron layers).

The Neuron Update Mode

The first thing we need to do is to calculate an error vector by subtracting the output of the neural net (for some given input) from a given target vector.

We apply the **HTStep** function to the error vector and update the response of the initial layer of neurons used in feed forward mode with some fraction of the values obtained (say c/2k 0 < c < 1). We then apply the **HTStep** function again and update the next layer of neurons as per Figure 2.

In each case the error vector goes through n (1<=n<=2k) applications of the **HTStep** function to the neurons and the response of the neurons in feed forward mode will go through a further 2k-n applications of the **HTStep** function giving 2k applications in total (a Hadamard transform, inverse transform pair).

Since the Hadamard transform is linear, all the fractional improvements in response will then sum together in the result vector. Even if a single neuron is responsible for the error, all the neuron layers in the net (and 3(2^k-1) of the neurons) will have a chance to participate in correcting that error. A further refinement is to update the response of each neuron with a random frac-

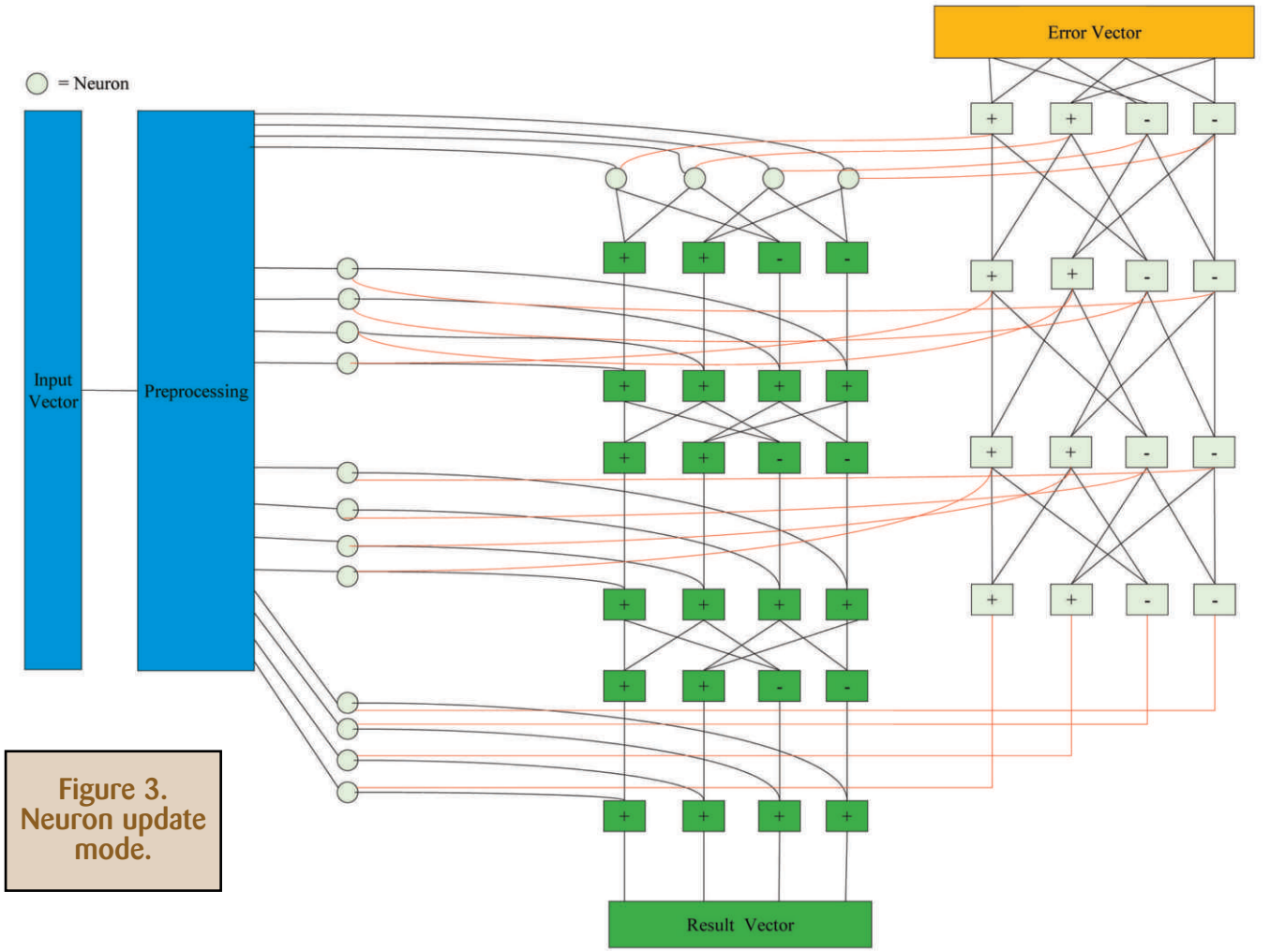

Figure 3. Neuron update mode.

tion of the error value that applies to it (e.g., rnd()*c/2k rather than c/2k). This de-correlates the errors the neurons make and gives a much-improved learning ability (including a simulated annealing effect resulting from the summing together of individual neuron errors into noise).

Network Behavior

The main advantages of this type of neural net reside in speed and simplicity and the ability to train the net with as few as 10 iterations through the input-target training set.

A disadvantage is that the output values of at least a portion of the neurons must cohere for a particular input or the result vector will simply contain low-level noise. This can reduce the ability of the net to generalize, especially with simple types of neurons. Nevertheless, this neural net topology can be extremely effective for many applications. SV

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```
log2VectorLen=k                    // 2^k vector elements
vecLen = 1 shl log2VectorLen       // shift left to get vector
length
halfLen = vecLen shr 1             // shift right by one (div by 2)
dim tempArray[0 to vecLen-1]       // temporary array
dim vector[0 to vecLen-1]          // vector array
recip = 1/sqr(2)                   // (=.707 app.)

// Layer function
function HTStep()
  lower = 0
  higher = halfLen

  for j = 0 to vecLen-1
     tempArray[j] = vector[j]      // copy data
  end for

  for i = 0 to vecLen-2 step 2
    a = tempArray[i]
    b = tempArray[i+1]
    vector[lower] = (a+b)*recip
    vector[higher] = (a-b)*recip
    lower = lower+1
    higher = higher+1
  end for
end function
```

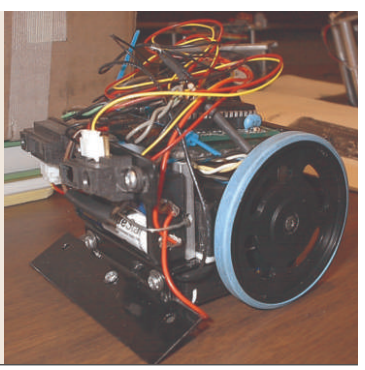
Table 1. The HTStep function.

About the Author

Sean O'Connor is an engineer with Marco Beverage Systems, and is a student with The Open University.

Further information on Hadamard Transform neural nets is available online at **http://homepage.eircom.net/~xe951/net.htm**

International Robot Competition Needs *You!*



If you're reading this magazine, you've either built a robot or would like to see the projects that others have built. It's time to bring those robots out of your garage and show the world your stuff! ROBOlympics, sponsored by the Robotics Society of America and *SERVO Magazine*, is bringing robot builders from across the world to compete in San Francisco, CA.

Fujisoft is sponsoring the annual SumoRobot event. If you've got what it takes, they're promising $2,000.00 to the winners of both the remote control and the autonomous 3 kg classes. The RSA is promising $300.00 to the winner of the 500 g autonomous sumo class.

If sumo's not your sport, try line following or maze solving. These simple classes of robots are easy to build, yet can still pay for your trip if you win! If you're more experienced, you should enter the walker challenge, in which robots with three or more legs must traverse an obstacle course in a race against time.

Most of you know combat robots from BattleBots and Robot Wars. Well, just because the TV shows are gone, it doesn't mean that the action has stopped. Eight classes of fighting robots, weighing up to 340 pounds, will compete for a purse of over $7,000.00.

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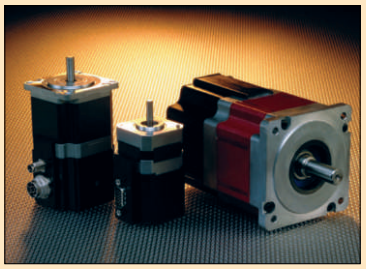

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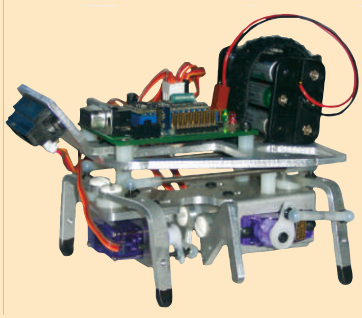

The New Hexapod Walker

Robodyssey Systems, LLC, of Trenton, NJ, recently unveiled its latest hexapod walker kit, "The

Adapt9S12DP256 *features Motorola's new 24MHz HCS12 microcontroller chip, with 84 I/O, 16 channels of 10-bit analog-to-digital, 256K Flash, 12K RAM, 4K EEPROM, two RS232 interfaces, I2C, 8-channel PWM, dual CAN interfaces, and much more– all on a 3.25 in. x 2.3 in. board! Includes DBug12 Flash-resident debug/monitor.*

Evaluation Package (shown) includes module, two prototyping cards, serial cable, DC power supply, and CD-ROM. Fully-functional 30-day version of ImageCraft C compiler (ICC12 Pro) included!

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Technological Arts

Ant." The Ant is a rugged, all-aluminum chassis, walking robotic platform that measures less than four inches long by four inches wide. It is powered by three powerful mini servos, upgradeable to metal gears, all for less than $20.00.

This easy to assemble robot includes heavy-duty stainless steel linkage with hobby aircraft ball ends and sockets, rubberized feet for better traction, and a new geometry on the middle legs that provides ample lifting power for any load. The Ant is drilled and tapped to accept all the Robodyssey accessories. The heavy-duty aluminum chassis and electronics deck are easily drilled and tapped for flexibility. Ant comes in a variety of configurations, starting with the ready-to-use Bare Bones model, with everything but the electronics, for less than $100.00, to models completely assembled, tested, and programmed for true desktop navigation.

Two controllers are available: the Robodyssey Advanced Motherboard and the New Robodyssey PicPak. Robodyssey Advanced Motherboard is pin for pin compatible with most 24-pin microcontrollers, including the BasicX-24 from Netmedia, which is programmable in a language that is a subset of the popular programming language "Visual Basic."

Robodyssey also manufactures the "PicPak" controller board for the Microchip 16F876 family of Pic controllers. The 16F876 can be programmed in Assembly, PicBasic, or "C" Compilers. Ant is unique in size and flexibility and will soon be convertible to a rolling platform with a new rolling conversion kit.

For further information, please contact:

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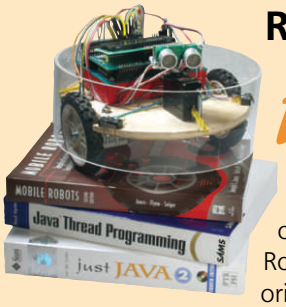

Recently, RidgeSoft™ announced the immediate availability of RoboJDE™ Java™ enabled robotics software development environment, version 1.1. RoboJDE opens the door to object-oriented software development for educational and hobby robotics projects. By providing a modern, easy to use, software development environment built for robotics applications, RoboJDE enables students and hobbyists to quickly and easily develop intelligent robotics software.

RoboJDE provides an easy to use integrated Java development environment, a robotics class library, and many example programs, including a complete mini-sumo robot program. In addition to a comprehensive Java interface to the HandyBoard and Sumo11 controllers, RoboJDE provides built-in support for a variety of sensors and actuators, as well as many software building blocks for programming intelligent robots. RoboJDE is free for evaluation and may be downloaded from the RidgeSoft website.

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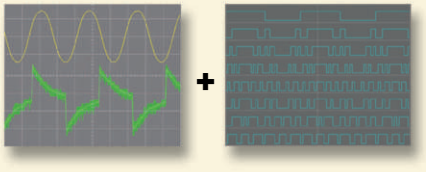

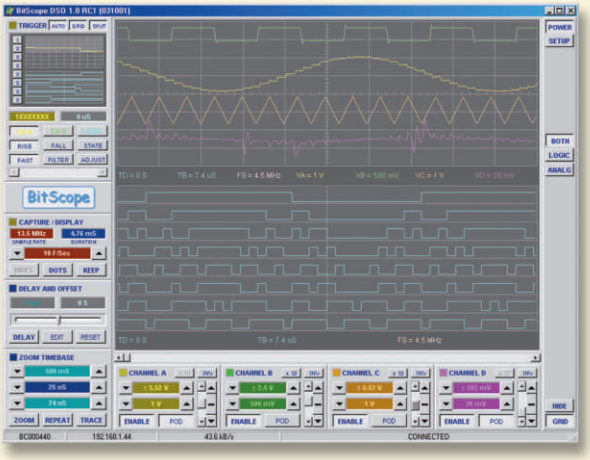

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Robotics Resources:

by Gordon McComb

Though many robots are constructed out of machine screws and other hardware, quite a few are held together solely or partially with glue. Modern adhesives are chemical concoctions designed to bond two surfaces together, and the nature of those surfaces depends a great deal on whether a given adhesive will make them stick. In this month's Robotics Resources, we look at adhesives available to the consumer. These adhesives can be purchased at craft, hobby, hardware, and home improvement stores.

Adhesive Setting and Curing

All adhesives bond by going through a number of phases, notably setting — or fixturing — then curing. During the setting phase, the adhesive transforms from a liquid or paste to a gel or solid. Though the adhesive may look to be "hard" when set, it is not yet very strong. This requires curing. Setting times for most adhesives are measured in minutes or even seconds. But curing takes a lot longer — typically 12 to 24 hours.

The curing process varies by adhesive. As a background, here's a short run-down of the most common curing methods of modern adhesives.

- **Chemical reaction.** Most adhesives cure through some chemical reaction, so this is really a generic curing method. The reaction begins via a number of means, such as the mixing of a resin with a hardener, contact with an activator, exposure to air and/or moisture, or contact with an acidic or alkaline surface (i.e. anionic reaction). The exact chemical reaction isn't critical to our understanding of the adhesive in order to use it, but in the interest of a better bond, it helps to know the basics of the process.
- **Catalytic.** Catalytic curing relies on a chemical reaction where at least one of the components in the reaction is not altered. Note that this isn't the same as a solvent cement that may or may not alter the material being bonded.
- **Anaerobic reaction.** This class of adhesive — commonly used for thread locking applications because of its high sheer strength — cures when it is deprived of oxygen.
- **Pressure sensitive.** Pressure applied to the adhesive begins a curing process. They are most common in adhesive tapes. Or sputum on papyrus (works well for pyramids!).
- **Heat (exothermic).** Many adhesives give off heat while curing, and this heat accelerates the curing and makes it complete. Two-part epoxy is a good example of this type of adhesive.
- **Light.** Specialty adhesives react to ultraviolet or visible light, and set when exposed to a bright light source. The brighter the light, the faster the adhesive cures. A common light-sensitive adhesive is used to secure rear-view mirrors directly onto windshields of automobiles.

Safety Concerns When Using Adhesives

Though some adhesives are non-toxic, many are poisonous, and can cause serious illness, even death. Use common sense when working with

any adhesive. Read the label thoroughly before use. Don't smoke, eat, or drink when applying an adhesive, and don't use them around open flames. When finished, wash up with warm water and soap. When using the really nasty stuff, like most epoxies, download and print the materials safety data sheet (MSDS) for the product, and keep it handy. These data sheets can be found at the manufacturer's website, which these days is usually indicated on the product packaging.

About General "Household" Adhesives

I'm grouping a large and admittedly diverse collection of adhesives under the moniker of "household," because they are traditionally used for general household bonding chores. These adhesives — sold by Loctite, Elmer's, Weldbond, and dozens of others — are commonly available in discount and department stores, home improvement and hardware stores, online supply outlets, and more. They are an ideal first choice for a wide variety of basic gluing needs. Household adhesives include the following binder types:

- Casein glues are derived from the protein of cow's milk, sodium caseinate. Popular applications for casein glues include paper and wood bonding.
- PVAC (polyvinyl acetate) dispersion adhesives are among the most popular general-purpose glues now available. Most of the white and yellow "woodworking" glues — such as those from Elmer's and Weldbond — are PVAC-based. They are water-based, easy to clean up, and inexpensive. Use them with porous materials.
- Styrene butadiene rubber (SBR) binders are among the most common of all water-based adhesives, used for both household and automotive applications. The adhesive remains rubbery, is typically used to form gaskets and sealants. This type of adhesive is popular for "temporary" bonds — when you want to glue something today, but want to be able to take it off tomorrow.
- Silicone-based adhesives are used for both gluing and sealing, and are used for similar tasks as SBRs. They can be used to bond most any non-porous surface to another. A common trait of silicone adhesives is that they remain elastic, even in cold temperatures. Most silicone adhesives cure at room temperature (hence their moniker, RTV, which stands for room temperature vulcanizing) by exposure to the moisture in the air.
- Urethane (or polyurethane) adhesive is a polymer plastic often used to bond wood, but is also able to bond other materials including many plastics and metal. It is particularly popular when bonding metal to wood. It cures by a catalytic reaction with water, and releases few toxins (compared to many other adhesives) into the air. This family of adhesives is also referred to as MDI, which stands for methylene diisocyanate.
- Contact cement is based on various volatile organic compounds. Contact cement is designed for joining smooth porous and non-porous materials. As their name implies, these cements are designed to bond more-or-less instantly on contact. This is accomplished by applying a thin layer of the cement on one or both surfaces to be joined, then waiting a minute or so for the cement to partially set up. Popular contact cements include DAP Weldwood, as well as various brands from 3M, such as C-77.
- Solvent-based cements use a chemical that dissolves the material it is bonding. They can be tricky to use because if the solvent isn't precisely matched with the material, nothing happens! Perhaps the most common solvent-based adhesive is for bonding PVC irrigation pipe. It is available at any hardware and home improvement store that sells PVC pipe. Other solvent-based cements are available for other plastics: ABS, polycarbonate, acrylic, styrene, etc. Testors (and others) makes a solvent cement specially formulated for bonding polystyrene-based plastic models. These can be purchased at hobby and craft stores.

Adhesives are commonly sold in tube or bottle form, but others — notably those from 3M — are meant to be sprayed on. 3M Photo Mount is a popular spray adhesive that is used to bond paper, foam, and other lightweight materials. Because it can be sprayed on, it is useful for bonding large surface areas, such as thin aluminum sheet to wood, plastic, foam, or some other substrate.

About Two-Part Epoxy Adhesives

Two-part epoxy adhesives are thermoset polymers consisting of a resin and a hardener. Separately, these materials remain in a liquid form. When combined, the hardener reacts with the resin, and the mixture begins to set quickly. Two-part epoxies are known for three distinct advantages. First is that the liquid of the epoxy is rather thick, and has good gap-filling qualities. This means you can use it to join surfaces that are not precisely aligned to one another. Second, epoxies set up and bond relatively quickly, from 5-30 minutes (however, some epoxies are designed to set up much more slowly). Epoxies can bond to many surfaces, including paper, wood, metal, fiberglass, most plastics, and fabric. And third, once set, epoxies are extremely hard and impervious to moisture, most corrosive chemicals, even oils.

The typical package of epoxy

adhesive consists of two tubes or bottles: one is the resin and the other is the hardener. The tubes are separate in some products, and in others, they are joined as one unit, with a single "plunger" in the center for accurately metering the resin and hardener.

Note that so-called five or thirty minute epoxies represents the setting time, not the curing time. It takes 12-24 hours for most epoxies to cure 60 to 80%, then the remainder over a period of a several weeks (curing is faster with warmer temperatures). Once cured, the bond achieves its maximum strength. Epoxies cure by exothermic action, meaning heat is generated during the curing process. The faster the epoxy cures, the more heat that is given off.

About Acrylic Adhesives

Acrylic adhesives are similar to the epoxies above in that they are composed of two parts, in this case, a base adhesive and an activator. Acrylic adhesives are known for their strength; they can be every bit as strong as epoxies, if not stronger. While there are many acrylic adhesive products available, a typical method for applying them is to coat one surface to be bonded with the activator, and the other with the base adhesive. The bond is made very quickly, so it is very important the surfaces are brought together and aligned properly.

About Super Glue

Super Glue is something of a trade name, but it's also increasingly used as a generic term for a family of adhesives known as ethyl cyanoacrylates, or CA. This adhesive is a space-age bonding agent that — thanks to its molecular structure — is able to bond most anything within seconds. CA glues cure upon contact with slightly alkaline surfaces. Moisture on the surfaces that are joined neutralize a stabilizer in the CA glue so that the surfaces bond to one another. Unlike many other glues and adhesives, cyanoacrylates do not require heat or other chemicals (e.g., an activator or hardener) to cure.

For all their benefit, CA glues can be finicky. If used incorrectly, they may provide only a weak and temporary bond. Keep the following in mind when using cyanoacrylate adhesives:

- Though some CA glues are available as a heavier-bodied gel, the most common cyanoacrylate is water-thin. Typical CA glue will not fill voids in the materials being joined.
- CA glues are much more susceptible to bond spoilage from dirt and oils than most adhesives. Clean the surfaces to be bonded first.
- The best cyanoacrylate bond uses a minimum of material, applied to just one surface, and not both. Use too much and the bond is considerably weakened.
- Unless you purchase a special industrial formulation, avoid exposing any CA glue joint to heat or sunlight. The bond will become very weak, and may even spontaneously come apart.
- Cyanoacrylate glue in the bottle or tube has a relatively short shelf life. The "optimum" shelf life depends on the mixture and storage temperature, but don't expect longer than 12-18 months.
- Though cyanoacrylate glues set (or "fixate") in under a minute, they are not fully cured for another one to four days.

About Hot Melt Glue

Most folks have seen hot melt glue. This adhesive comes in stick form, and is heated by a special gun-shaped applicator, or even with an electric pot or crucible. Depending on the type of hot glue being used, melting temperatures range from 250° to 400° F. The cooling process doesn't take long — under a minute — and the glued joint is already strong.

Though it may come as a surprise, hot melt glue isn't glue at all, but plastic — or more specifically, a polymeric thermoplastic with a reasonably low melting point. Adhesion occurs as the molecules of the polymer contract and harden. A common polymer used for consumer hot melt glue sticks is ethylene vinyl acetate (EVA). Many glue stick manufacturers use additives to enhance the properties of the EVA material.

For most tasks, hot melt glue is applied using a glue "gun" and glue sticks; both are available at hobby stores, arts and crafts stores, and most home improvement stores. Cost is under $20.00 for a gun and a half dozen sticks. You can get a regular size glue gun for bigger household jobs

The glue is heated to a viscous state in a glue gun, then spread over the area to be bonded. Not all glue sticks have the same melting point and hardness. The typical glue stick from the hardware or craft store is low-temperature, and sets to a semi-rigid state (the glue is not rock-hard when set). This type is acceptable for use with most plastics, to avoid any "sagging" or softening of the plastic, due to the heat of the glue.

However, for higher-bond yields for metals, closed-grain wood, and heavier plastics, select a high-temperate glue stick.

Some Favorite Adhesives

Everyone has a favorite adhesive, and everyone is fond of recommending their favorite to those who ask. I recently polled some robot building friends and got some of their favorites, as well.

• **Shoe Goo.** Intended to repair worn or broken shoes, Shoe Goo is an all-purpose sealer/adhesive that sets up to a semi-spongy and quite resilient mass. Curing time is rather slow — from one to five days — but curing can be accelerated by applying heat from a hair dryer. For large or thick areas, apply several coats of Shoe Goo to build up the material, rather than one big clump at once.

• **Household GOOP.** This product belongs to the large family of silicone or silicone-like adhesives that also include Plumber's GOOP, Crafter's GOOP, Sportsman's GOOP, and others. Household GOOP remains flexible even after curing. Most can also be peeled off with just a little effort, allowing for "temporary" bonds. Along similar lines is Dap adhesive, another favorite of mine.

• **Pro Bond.** This single-part polyurethane adhesive can be used to bond wood, plastics (most, anyway), metal, leather, paper, and other porous and non-porous materials. This is a good glue when you need to "bond anything to anything."

• **Super Glue.** Everyone calls CA glue "super glue," but this is really a brand for a number of adhesive products. In this case, I'm talking about Super Glue's Super Glue (cyanoacrylate), available in a number of consistencies. Use the thicker "gel" formulations when the parts are not closely fitting. Super Glue sells products that come in tubes, bottles, even pens. The parent company (Pacer Technology) also sells ZAP (popular among R/C hobbyists), Bondini, and other brands of CA glues.

• **J-B Weld.** Like Super Glue, J-B Weld is a company, as well as a product. Most adhesive connoisseurs know J-B Weld as a "bond to anything" two-part epoxy resin that contains fine particles of iron and steel. The adhesive bonds metal to metal, metal to plastic, and other variations of both porous and non-porous materials. J-B Weld is popular among auto restorers and weekend mechanics, and indeed, the product is available at many auto supply stores around the globe.

• **Barge All Purpose Cement.** Trust a shoe repair shop to know what contact cements are strong enough to tack heels onto boots. Barge products are not as easy to find as some others, but it'll glue most materials, particularly porous, with a most-permanent bond. Recommended when strength is critical. As with most contact cements, to use it, you apply a coat to both parts to be bonded. Wait until the adhesive starts to dry (it'll get tacky to the touch), then press the parts together.

• **Permatex.** Representing both a brand and a popular product, this stuff is really a gasket-making compound, but it can also be used as a sealant and flexible glue. Most adhesives cure to a hard mass, but Permatex is designed to stay flexible, like silicone RTV. This allows you to more easily disassemble bonded parts, should you ever need to. An advantage of Permatex is that it is very resistant to heat. It's commonly used in automotive and motorcycle repair. Other good products in the Permatex line include Permatex Cold Weld Bonding Compound. This two-part epoxy contains iron oxide filler, and once cured, can be sanded, drilled, and cut.

USING HOT MELT GLUE

All glues take time to "set." For most glues, the longer the setting time, the stronger the bond. That's why a 30-minute epoxy is better, all things considered, than a 5-minute epoxy. But the problem with slow-setting glues is that you either need to clamp the pieces together while the joint hardens, or sit there holding everything in place. For some jobs, neither is practical.

Enter hot melt glue. Hot melt glue is like a sticky wax. It melts at temperatures of 250 to 400 degrees, and congeals as it cools. The cooling process doesn't take long – under a minute – and the glued joint is already strong. Additional strength comes as the glue cures, but the pieces are already securely held together. For most tasks, no clamping is necessary.

You need only a hot glue "gun" and glue sticks; both are available at hobby stores, arts & crafts stores, and most home improvement stores. Cost is under $20 for the pair. You can get a regular size glue for bigger household jobs, but for most robotics applications, the small "craft" gun is all you need. They're cheaper, too.

The glue is heated to a viscous state in a glue gun, then spread out over the area to be bonded. Glue sticks are available in a "normal" and a low-temperature forms; the low-temperature glue is better with most plastics, to avoid any "sagging" or softening of the plastic, due to the heat of the glue.

Finally, using a hot melt glue gun is easier when the weather is warm. In cold weather, the glue sets very quickly. If it's cold out, move the project indoors. It'll give you a few more seconds to position the pieces together before the glue sets up.

Though the hot melt glue is not heated to dangerous temperatures, it's still rather uncomfortable to have a dollop of melting ooze land on your arm or leg. Exercise care when using the glue gun, and keep it away from children. The low-temperature gun and glue sticks are safer (though the glue re-sets more quickly), but can still burn skin.

Sources for Glues and Adhesives

Look here for some retailers and manufacturers that specialize in glues and adhesives that have particular merit for robot building. On the manufacturer front, there are actually hundreds of makers of various glues, adhesives, and cements, and I've listed only a few of them here as representative of what's available. Visit their websites for technical date, application information, and materials data safety sheets.

Of course, don't forget the local department, home improvement, and hardware store. Most carry a wide selection of glues and adhesives.

Adhesive Online
www.adhesive-online.com

Source and technical data for a variety of adhesives, including silicone RTV, Super Glue, and epoxy.

Ambroid / Graphic Vision
www.ambroid.com

Ambroid makes glues: Ambroid liquid cement (general adhesive), styrene plastic cement, Proweld (for ABS, styrene, butyrate and acrylic plastics), EZ Mask peel-away liquid, and Tac-N-Place.

The products are available in many hobby stores and in arts and crafts stores.

ArtSuppliesOnline.com
www.artsuppliesonline.com

Art supplies: craft boards (such as foam board), plastics and adhesives, and lots more. Their online store lets you browse by category, or search for specific products by name or brand. Check out their "Imaginative Manikins," small articulated wood models in the shapes of people and animals.

Clotilde, Inc.
www.clotilde.com

Online and mail order (printed catalog) sewing and quilting supplies. Look over things like fusing tape (partially melts when heated), small tools, rotary cutters (useful for foam core and other lightweight laminates), and elastics.

Cyberbond
www.cyberbond1.com

Manufacturer of hobby and automotive adhesives. Technical details about each product are available at the site. Available at retail stores; some products available online.

Dick Blick Art Materials
www.dickblick.com

Complete line of craft materials and art supplies. Also local stores (predominately in the Midwest and Great Lakes areas of the US).

FLAX Art & Design
www.flaxart.com

Art supplies: adhesives, paints, substrates, craft, drafting.

Hot Melt City
www.hotmelts.com

Hot melt glue guns, glues. For both hobby and professional use. Full line catalogs are in Adobe Acrobat PDF.

IPS Corp.
www.ipscorp.com

IPS makes the WELD-ON brand of solvent cements for PVC and other

FIGURE 1. Though primarily a source for artist supplies, online retailers like Flax Art & Design often sell a variety of adhesives useful in the robotics craft.

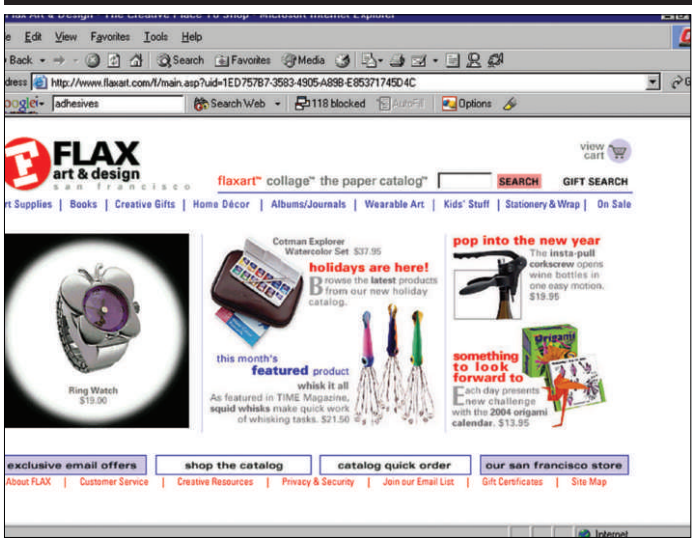


FIGURE 2. Arts and craft stores like Michaels stock a variety of adhesives, including epoxies and hot melt glues.

FiND MORE GLUE AND ADHESiVES!

Looking for additional sources of glues, adhesives, and cements? Try the following Google.com search phrases. As with the other listings here, most glue and adhesives makers do not sell to the public – unless you're purchasing by the 55-gallon drum. But for most companies, you can find their products at local hardware and home improvement stores,

- manufacturer glue adhesive
- manufacturer glues adhesives
- manufacturer glue OR adhesive
- manufacturer glues OR adhesives OR "solvent cement"
- manufacturer ca glue

FIGURE 3. 3M is one of the world's largest adhesive manufacturers. Their website contains copious information about their products. The information is also useful as a primer on adhesives in general.

plastics. Their consumer products are available at hardware and home improvement stores; their industrial products, including two-part epoxies and applicators, are available at plastics specialty outlets.

Material Safety Data Sheets (MSDS) are provided online. If you use these products, download these sheets and read them, as solvent cements — as useful as they are — aren't good for your health.

Loctite Corp
www.loctite.com

Manufacturer of glues and adhesives. Datasheets provided on the webpage.

Michaels Stores, Inc.
www.michaels.com

Michaels sells arts and crafts, both online and in some stores across North America and Puerto Rico — they're the largest such retailer, in fact.

MisterArt
www.misterart.com

The site bills itself as the "World's largest online discount art supply store." Looks to be true — they have a lot of stuff! Quite a bit of supplies for paint artists, as well as foam core, precision tools, and adhesives.

Nancy's Notions
www.nancysnotions.com

Online and mail order (printed catalog available) sewing supplies.

tesa AG
www.tesa.com

Makers of unusual adhesive tapes, including transfer tape, which is just the gooey part, without the backing. It's used heavily in manufacturing. Tesa products are available from retailers and distributors, but you can read up on it here.

3M Worldwide
www.3m.com

Manufacturer of a variety of industrial and consumer products. Many application notes are available on the website. Way too many to list here, so see **www.search.3m.com** to search the product database. Among the most useful products:

- Engineered adhesives (spray, tape, putty, reclosable fasteners (like Velcro, only more aggressive stickiness)
- Paints and protective coatings
- Abrasives (sandpaper, Scotch-Bright)
- Foils and tapes (metal, plastic, paper, duct, foam)

Uniplast, Inc.
www.uniplastinc.com

Uniplast makes hot glue guns and water-soluble adhesive sticks. They offer industrial and consumer models of glue guns. Glue sticks are available in traditional clear, or in colors, as well as glow-in-the-dark. **SV**

ABOUT THE AUTHOR

Gordon McComb is the author of the best-selling *Robot Builder's Bonanza*, *Robot Builder's Sourcebook*, and *Constructing Robot Bases*, all from Tab/McGraw-Hill. In addition to writing books, he operates a small manufacturing company dedicated to low-cost amateur robotics, Budget Robotics, **www.budgetrobotics.com**. He can be reached at robots@robotoid.com.

EVENTS CALENDAR

Send updates, new listings, corrections, complaints, and suggestions to: **steve@ncc.com** or **FAX 972-404-0269**

April is really shaping up to be a huge month for robot competitions — see for yourself! And please don't forget that now is your chance to find a local FIRST team and become a mentor. Share what you've learned here in the pages of SERVO!

For last minute updates and changes, you can always find the most recent version of the complete Robot Competition FAQ at Robots.net:

http://robots.net/rcfaq.html

— R. Steven Rainwater and Editor Dan

February 2004

22-26 **APEC Micromouse Contest**
The Disneyland Hotel, Anaheim, CA
This will be the 18th annual event for one of the best-known micromouse competitions in the United States. Expect to see some very advanced (and fast!) micromouse robots.
www.apec-conf.org/2004/APEC04_Home_Page.html

March 2004

9-10 **Emerging Robotics Technologies And Applications Conference**
Campbridge, MA
This conference explores how emerging robotics technologies are being used to develop entirely new markets and product categories, open additional lines of business, enhance existing product lines, and increase business productivity. (Sponsored in part by *SERVO Magazine*.)
www.roboticsevents.com

12-13 **AMD Jerry Sanders Creative Design Contest**
University of Illinois at Urbana-Champaign, IL
This year, robots will play Tetris by forming a completed puzzle out of nine standard Tetris shapes on a 36' x 36' playing field.
http://dc.cen.uiuc.edu/

13 **DARPA Grand Challenge**
Los Angeles, CA
An autonomous LA to Vegas cross-country, off-road race for a one million dollar prize. Not your average robot contest — especially if you didn't make that cut of 19!
www.darpa.mil/grandchallenge/

13-14 **Manitoba Robot Games**
Manitoba Museum of Man and Nature, Winnipeg, Manitoba, CANADA
This interesting assortment of robot events includes mini sumo, Japanese sumo, a robot tractor pull, atomic hockey, and robo-critters.
www.scmb.mb.ca/mrg.html

20-21 **RSA ROBOlympics**
Fort Mason, Herbst Paviliion, San Francisco, CA
Possibly the largest robot competition of 2004 and includes robot fighting, FIRA robot soccer, a bipedal race, BEAM, LEGO Mindstorms, nano sumo, and more. Over $10,000.00 in prize money is offered.
(Sponsored in part by *SERVO Magazine*.)
www.robolympics.net

28 **University of Florida Student Robotic Competition**
University of FL Conference Center, Gainesville, FL
This is the only robot contest you'll see where the robots are required to obey Asimov's three laws as part of the rules!
plaza.ufl.edu/niezreck/Robots_Competition_2004.html

April 2004

15-17 **FIRST Robotics Competition**
Georgia Dome, Altanta, GA
The national championship event for the FIRST student robot competitions. It's the largest FIRST event of the year and is open to the public.
www.usfirst.org

16 **Carnegie Mellon Mobot Races**
Wean Hall, CMU, Pittsburgh, PA
The 10th annual occurance of the now famous

CMU Mobot race. Autonomous robots race to complete a complex course, passing through 18" finish gates along the way. Sponsored by the School of Computer Science.
http://www-2.cs.cmu.edu/~mobot/

16-17 OTEA National Robotics Competition
Veterans Memorial Coliseum, Marion, OH
This contest is intended to replace the defunct RI/SME Robotics Challenge. Includes several autonomous robot events, as well as a radio-controlled event for beginners.
www.ohiotech.org/competitions.html

17 RoboRodentia
California Polytechnic State University, San Luis Obispo, CA
This is something like a micromouse event except that in addition to navigating the maze, the mice have to pick up balls and return them to a "nest."
http://ieee.ee.calpoly.edu/ieee_cs/

17 UC Davis Picnic Day MicroMouse Contest
University of California, Davis campus, CA
Every year, UC Davis has a campus-wide event known as Picnic Day. And every Picnic Day includes the annual MicroMouse contest. The event follows standard MicroMouse rules.
www.ece.ucdavis.edu/~ieee/umouse/umouse.html

18 Trinity College Fire Fighting Home Robot Contest — Trinity College, Hartford, CT
An autonomous robot must move through a mock house, locate a fire, and extinguish it. This year's contest will be the first without Jake Mendelssohn at the helm. He will be missed.
www.trincoll.edu/events/robot/

20-22 DTU RoboCup
Technical University of Denmark, Copenhagen, DENMARK
Imagine your typical line-following contest. Now add forks in the line, ramps, stairs, gaps in the line, shifts from indoor to outdoor lighting, reversals of the line shading (white to black), and 50 cm "gates" though which the robot must pass.
www.iau.dtu.dk/robocup/about_robocup.html

23-24 Steel Conflict
Anaheim, CA
Radio-controlled vehicle combat.
www.steelconflict.com

24 RoboFest
Lawrence Technological University, Southfield, MI
A competition and exhibition of autonomous LEGO robots. Designed to spur student's interest in science, engineering, programming, and technology.
http://robofest.net/

28 SAE Walking Machine Challenge
Union College, Schenectady, NY
This is *the* collegiate level contest for autonomous and tele-operated walking robots. For 15 years, some of the most innovative robot designs around have turned up at this event.
www.sae.org/STUDENTS/walking.htm

May 2004

14 SPURT (School Projects Using Robot Techniques)
Rostock-Warnemunde, GERMANY
Autonomous robots (less than 20 cm wide) race on the SPURT track.
http://spurt.uni-rostock.de/

15 Atlanta Robot Rally
SciTrek Museum, Atlanta, GA
There is an open contest where builders choose their own goal for their robot, as well as the vacuum contest for autonomous household vacuums.
www.botlanta.org/Rally/

18-20 Singapore Robotic Games
Singapore Science Centre, SINGAPORE
This is a large event containing a legged robot obstacle race, as well as a legged robot marathon. The latter includes wall climbing, pole balancing, gladiator, micromouse, sumo, and soccer.
http://guppy.mpe.nus.edu.sg/srg/

CUTTING EDGE ROBOTICS:

A Multi Function Robot

PART 2

by John Myszkowski

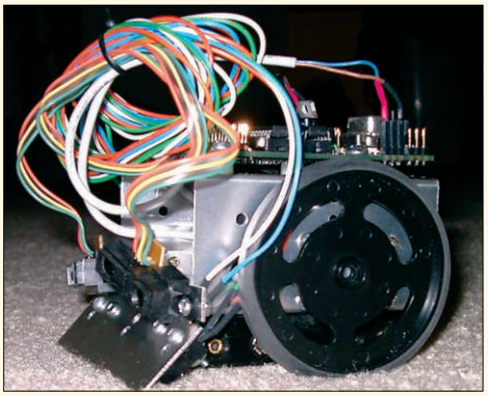
Last month, we learned how to drill, cut, and bend sheet aluminum while employing basic safety measures. At this point, you should have a nice, shiny robot chassis all ready to go. This chassis is going to be the base for your very versatile robot. This installment of the "Cutting Edge Robotics" project will bring us into the world of robotics competition.

The Way of the Sumo

We are going to make an autonomous mini-sumo (wrestling) robot (Figure 1). The mini-sumo is not exactly a Battlebot, but it will be able to compete in a battle arena.

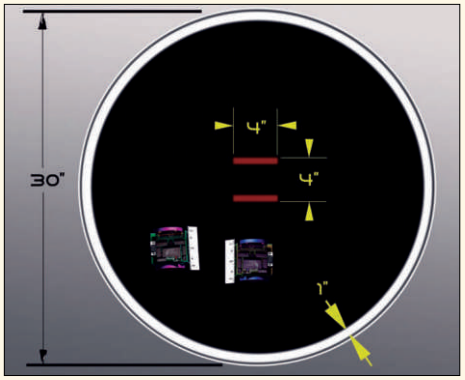
A sumo-bot competition is one of the most accessible robotic games for kids and adults alike. Anyone with a robot can compete. New sumo robotics fight clubs are forming constantly. The fighting arena or the sumo ring is a circle, 30" in diameter (Figure 2). It is black with a white border and two starting reference lines, which are brown in order to be non-reflective to IR (infrared).

Figure 1. A ready to go mini-Sumo.



The object of this competition is to push the enemy robot out of the arena. However, you don't have to worry about your "baby" getting hurt. Just like in the Japanese sumo wrestling style, damaging the opponent is against the rules. This is a competition of your hobby engineering skills, not the robot's strength.

Figure 2. Mini-Sumo ring design with two mini-Sumo robots poised to do battle.



Sense of Danger

In order to compete successfully, the robot will need to "see" the enemy sumo. It will need to sense the edge of the arena to avoid falling out. It will also need to decide what to do when it senses these hazards.

To make your robot fully autonomous, it will need a brain. The robot brain is one or more computer chips on a PCB (printed circuit board) and is usually referred to as a "controller" (Figure 3). Its main job is to sense the environment and react accordingly. In other words, it reacts as it is pro gmmed to react, but makes decisions based on input.

The controller needs to have the ability to read a variety of sensors to detect the edge of the arena and find enemy robots. It also needs to control

Figure 3. A variety of robot controllers that can also be used to control a Sumo-type robot. From top left clockwise: TAB SUMO-BOT, TAB Build Your Own Robot Kit, Mark-III, Sumo-11, and ARC-1.1 controller.

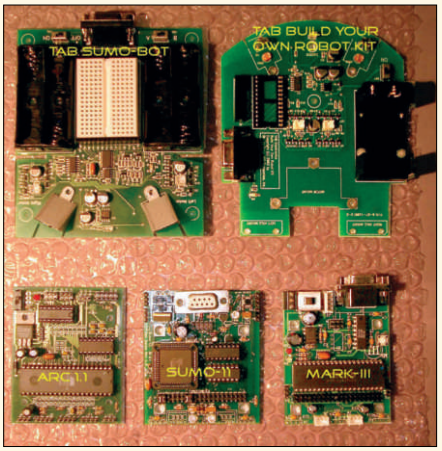


Figure 4. Two line sensors (all wrapped up) and two object sensors.

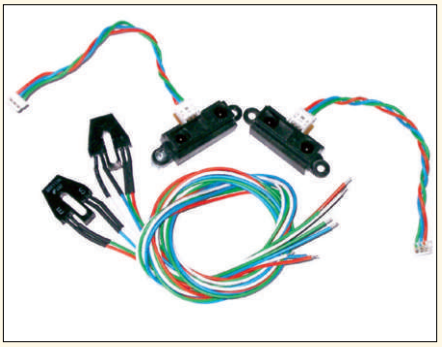


Figure 5. Two tiny contenders: Cyclops and Bob. Built and operated by Bronson Silva. It's a real handful.

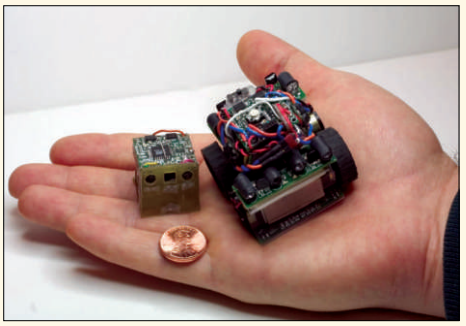
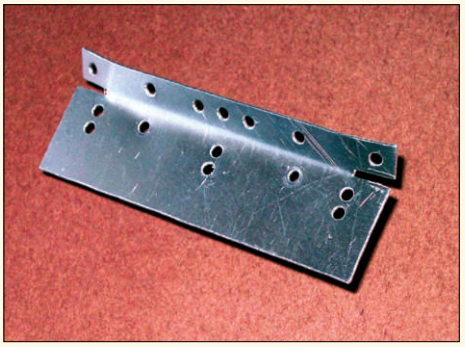


Figure 6. Finished Sumo scoop. Ready to be assembled and installed.



the outputs (Figure 4).

Motor Control

Outputs are needed to control the two DC motors. One type of output is a relay that turns a DC motor on or off. Ideally, it would be good to be able to adjust the motor speed according to need. To do this, we need an electronic switch that responds to PWM (pulse width modulation).

The Choice is Yours

Many people have spent a lot of time to make the "ideal" controller for a robot. The result of all this labor is that we now have many choices of pre-assembled or kit controllers (Figure 3).

In this part of the project, I am using the sumo11 controller board from Dan Gates. At the time, it was the most suitable option for my purposes, but you can choose a different controller. For your reference, I have prepared a compatibility chart (see Table 1). A number of important features were considered, namely the PCB footprint and minimum I/O.

The compatible controller boards will fit in our chassis with little or no modification; however, this does not mean they are all the same. You may choose your controller type on the basis of cost, availability, CPU type, ease of assembly, extra I/O, compatibility to other projects, software availability, software tools, etc. Throughout this article, I will mention the most necessary functions the controller needs to have. It wouldn't hurt to have more than one controller. Keep in mind that all compatible controllers will work with LEGO products ... but that's another story.

Defining Moment

Metalwork itself does not make a robot. A loose definition of a robot states that it needs to sense its environment, follow preprogrammed instructions, and make decisions based on input. Our autonomous mini-sumo robot is capable of all these things — and more.

The small size of our mini-sumo is made possible by the incredible technology buried inside the controller.

Just a few short years ago, the electronics part of the robot would have had to reside on a desk, tethered to the robot chassis. What we are making today is a "miracle" of modern technology. We have made great strides in robotics. This has happened in just a few years, since the introduction of the microprocessor.

The Future is Cubed

The interesting part of this "mira-

Figure 8. It's a good idea to make it a habit to check finished parts for a proper fit. It's best if it is done before it is painted or any parts are mounted.

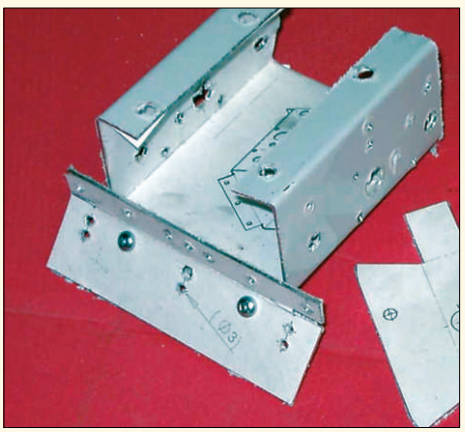


Figure 7. Bending the scoop can be carried out in a regular vise. Shown here is the scoop being persuaded to bend.

Jason Rocks The ECRG

My high school's robotics team has been competing for three years in robotics events, but my friends and I still do our finishing touches the night before, in spite of well-intentioned deadlines. We make a habit of getting to the competition early to have time to set up, make last-minute changes, and see old friends.

I had entered five robots, which seemed like a great idea, until I realized how much running around was involved. My C.E. Silver robot did quite well, considering that I forgot to debug the program; all the robot did was spin in circles. The soft, molded tires won the round; they had so much traction that the competition couldn't push me out of the arena.

In the R/C (remote controlled) Sumo competition, the competitors fully control the operations and movements of the robot remotely. To keep the cost of building the robots down, a tether wire can replace an RF remote, as seen with my RC Sumo, Cutting Edge.

Jason does some last minute soldering.

Be aware that some competitions use a point system to determine the final competitors, as opposed to eliminations. At this year's ECRG, my matches went very well. I even won one match after losing control of a wheel due to a broken wire; this shows the value of those soft rubber wheels. Competitions are great experiences that provide fun and education.

Jason's Bio

Jason Myszkowski, a high school student, has been competing in robotics events for three years. He also enjoys role-playing games and working with computers.

cle" is that it's not finished yet. The mini-sumo is supposed to fit inside a 10 cm square and weigh no more than 500 g. There are new sumo classes which require the size and weight to be even less; micros can only weigh 50 g and must fit in a five cm cube and the nano-sumo can only be 25 g and must fit inside a 25 mm cube (Figure 5).

There are a few people who have already constructed much smaller, fully functional robots. True nano-technologies will make it possible for such tiny, microscopic robots to do useful work in machine troubleshooting, maintenance, and even medicine.

Figure 11. The crease where the chassis was folded may be a problem spot. Check to make sure the motor will fit into the corner (top). Any interference between the motor and the chassis fold can be remedied with a few strokes of a file (bottom).

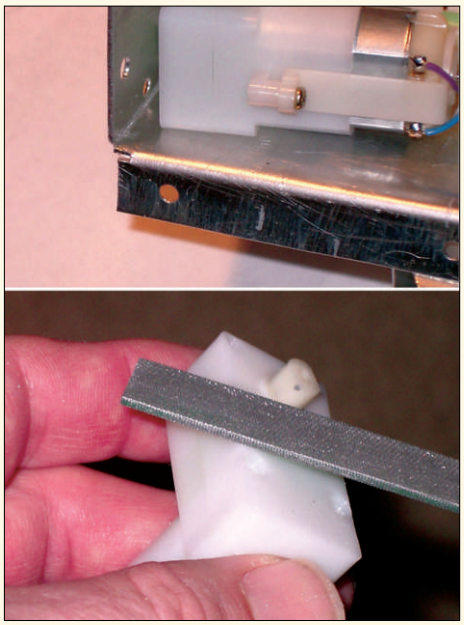


Figure 12. The controller is mounted on top of the chassis. Note the batteries. It is a good test platform, but the electronics should have been tested previously. A quick function test won't hurt after each step of assembly. It's easier to find any mistakes.

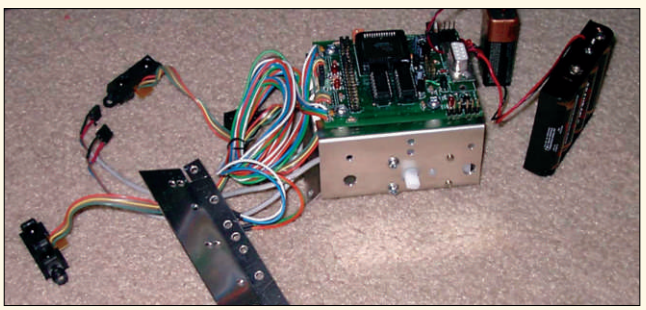


Figure 9. It is always a good practice to take off any sharp edges before assembly.

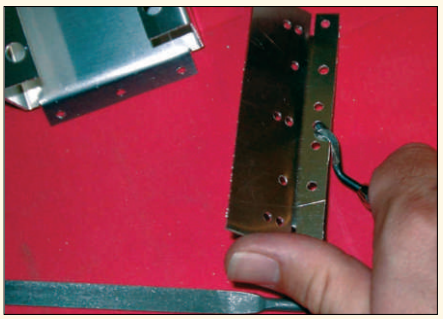
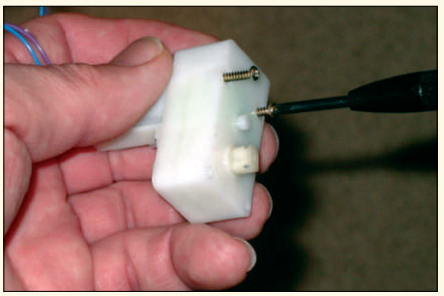


Figure 10. Two screws have to be reused for mounting the motor. First, they have to be removed.

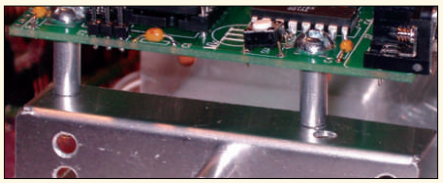


And Now for the Scoop

Now that the brainy part is over, we can start with the actual work. Keep in mind, you still have to remember the safety issues involved; now, we can start working and get our hands dirty. We only need to make one small item – the scoop (Figure 6). The rest of our components are purchased prefabricated.

To make the scoop, we need a small piece of aluminum, the layout sheet from this article, and some cutting and bending tools. For detailed instructions on the method and safety precautions, please refer back to last month's installment. First, drill and cut out the scoop

Figure 13. You can use plastic spacers or drilled/tapped/threaded standoffs. Whatever is easier to get will work. Just for variety, here I am using a set of metal standoffs that screw into the chassis first. The controller screws into the standoffs. This is more expensive than the prescribed hardware, but it is faster and easier to assemble. Whatever you end up using should be at least 1/4" long.



according to the drawing (Layout 1.) Then, bend it to about a 45 degree angle (Figure 7) and check to make sure it fits on the chassis (Figure 8). Make sure you remove any sharp edges before painting (Figure 9).

Your scoop is ready when the paint, if you chose to apply it, dries, but do not mount it yet.

Testing, Testing

Follow the assembly and test procedures provided by the manufacturer of your controller very closely. Sensors, battery clips, controller, and motors should now be tested. Connect all components together before they are installed.

It is time for a subsystem check. Load the test pro gm that came with your controller. Make sure all tests are passed before installing the electronics into the chassis. Finally, you are ready to install these components to create an electronic "spider" ready to be assembled.

Motive Power

The two gear motors are fitted to the chassis and fixed in place with four screws. Two of the screws from the motor will be reused and must be set aside for use (Figure 10).

It is necessary to keep your eyes on the fold in the chassis where the motor will sit (Figure 11, top). If the fold is not tight enough (too round), there won't be enough space for the motor to sit properly. This could cause uneven wheel rotation or gear binding.

You can fix any fold problems by filing the corresponding edge on the gear motor (Figure 11, bottom). Make sure the motor mounting holes are

References and Links

www.robotgames.net or **www.robotgames.com**
This is a great place to start looking. All kinds of hobby robotics information is located in this site. There are plenty of links and other contacts for your use. Photos of many sumo robots from all categories– from nano to full-size autonomous sumos – can be found here.

www.robotgames.ca
This is the home of the east coast Sumo and B.E.A.M. robotics. If you want more information about sumo competition, this is a good place to look. Photos from past events, descriptions of various events, and the official rules are all here, plus more.

www.junun.org
The Mark-III robot comes from this organization; details about the its controller are found here. You can find all the manuals and purchase everything from sensors and other components to full Sumo kits and pre-assembled controllers. You can also find the NANO or MICRO sumo controller here at a very attractive price.

www.1sorc.com
This is where you will find the Sumo-11 controller. Additional information on bare PCB's and expansions can be found here. The links will take you to the software and software tools you may need.

www.hobbyengineering.com
This site has a growing selection of hobby robotics components. This is a perfect place to find all the parts for Cutting Edge projects. The GM-type gear motors and the sensors can be found here. They also sell other items that will be required for future installments.

www.bugnbots.com/shop
This is the home of the B.E.A.M. kits on the east coast.

www.solarbotics.com
Many useful parts are here, including the GM-type of gear motors that you can purchase and circuit diagrams to reference.

www.barello.net or **www.barello.net/arc/**
Atmel-based robotic controller information can be found here. You can find the ARC-1.1, as well as other extremely useful and reasonably-priced robotics controllers. If you are dreaming of building an ANT-size Battle Bot, this is the place to look for the perfect controller.

www.geocities.com/bethmiller805@sbcglobal.net/index.html
Casey specializes in NANO robot parts and accessories. Check out his web site. He has a few gizmos you may find very interesting. He also makes expansion circuit boards for the NANO class robot.

www.novarobotics.com
This company often has finished metal parts and kits for Cutting Edge projects.

Figure 14. Line sensors mount on the outermost holes of the scoop. Two holes are provided for flexibility of adjustment.

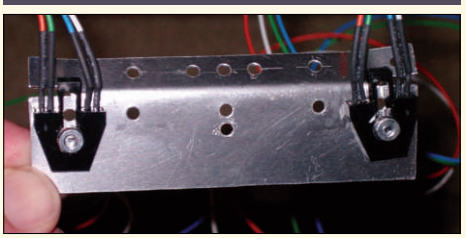
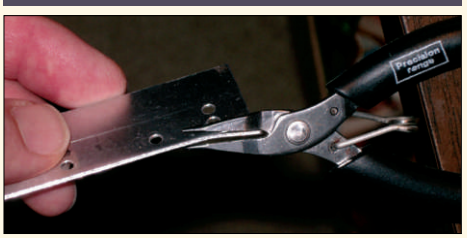


Figure 15. Bendable tabs on the scoop are for mounting the object sensors. Here they are being bent to about five degrees.



Component List

1 — Main chassis from the January, 2004 issue — **www.novarobotics.com**

1 — Scoop — **www.novarobotics.com**

2 — GM8 or GM2 gear motors — **www.HobbyEngineering.com** and **www.solarbotics.com**
GM9 or GM3 gear motors should also fit, but they do stick out the end of the chassis.

2 — Matching (GM8) wheels — **www.HobbyEngineering.com** and **www.solarbotics.com**
GMPW-x wheels fit the GM2/3/8/9 motors.

1 — Controller board — see article text and the compatibility chart [Table 1]
Sumo-11, Mark-III, or ARC-1.1

2 — Edge sensors — Fairchild QRB1134 from **www.HobbyEngineering.com**

2 — Object sensors — Sharp GP2D12, GP2D15, or GP2D120 (from **www.HobbyEngineering.com**) or whichever works best with your controller

1 — 4xAA battery holder — from **www.HobbyEngineering.com** or RadioShack

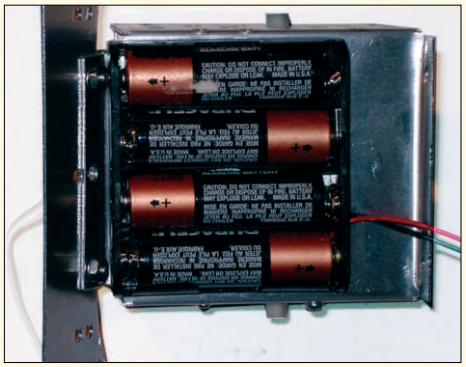
1 — Nine-volt battery clip — from **www.HobbyEngineering.com** or RadioShack

Double-sided tape, mounting hardware — from your local hardware store

Notes:
- Lock-nuts can replace the combination of nut and lock washer.
- No specific mounting screws have to be used — just drill holes for the size of screws you have. (Note that bigger holes allow room for adjustment.)
- My favorite screw size is 6-32. It fits all, but 4-40 is handy for the smaller holes. I try not to use the 8-32, but sometimes they come in handy. Anything beyond #8 is just too big for use with electronics.
- There are some things to consider regarding the length of the screws: If they are too long, then they may scratch something or may not go in all the way. But if they are too short, you may not be able to affix washers and nuts to it.
- There is no real precision required for the "Cutting Edge" projects, or at least nothing that a bigger drill bit, a file, or a hammer can't fix!

aligned with the mounting holes in the chassis. Reuse the two screws first. Do not tighten them. Insert the long 4-40 screws and nuts. Make sure the motor sits squarely in its place. Once all four screws are aligned, tighten them.

Figure 17. Mount the 4xAA battery pack on the bottom side of chassis. Locate it as close to the scoop as possible, without touching the screw to the battery pack.



Controller

The controller is mounted on top of the chassis (Figure 12). To accomplish this, you will need four each of:

Figure 18. The best place for the nine-volt battery is just under the controller board. Use double-sided tape to stick to the motors.

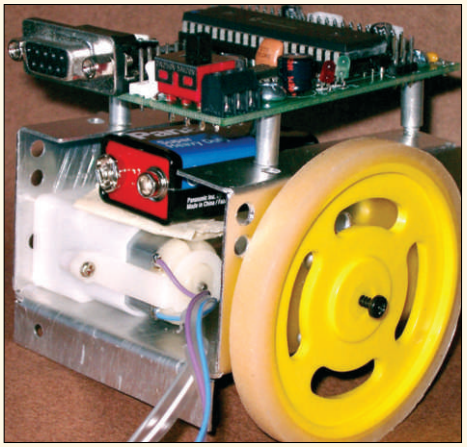
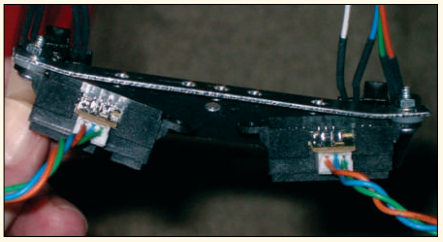


Figure 16. Object sensors are mounted on the bent tabs on the scoopusing only one screw. Note the plastic spacer between the sensor and scoop tabs.



3/4" screws, 1/2" spacers, nuts, and lock washers. The spacers have to go between the circuit board and the metal chassis. Once all four screws are in, tighten them securely (Figure 13).

Two Sensors' Worth

The sensors should be attached to the scoop at this time. You may add them after the next step, but it would be easier to attach the sensors before the scoop is attached to the chassis. The two outermost holes in the scoop are for mounting the IR line sensors (Figure 14). The two Sharp sensors locate the enemy robot (object). The scoop is a perfect place to mount them. First, bend the two tabs on the scoop about five degrees outwards (Figure 15). To mount the object sensors, you will need two each of the following: screws, plastic washers, lock washers, and nuts.

For this, 4-40 screws are a good size, but a 6-32 may also be used if you enlarge the holes.

Use only one screw per sensor. Insert the plastic washer between the sensor and scoop (Figure 16).

Scooper Duper

The scoop is just one part of what makes this robot into a sumo-bot. It is a very important component; without it, the sumo would be unable to push the opponent very effectively. It also helps to balance the robot and keep it from falling over.

Locate all the mounting hardware

listed above. Align the mounting holes in the scoop with the mounting holes in the chassis. Insert the screw from the scoop side. Next, place the washer and the nut on the screw, finger tight. Repeat with the second mounting hole. You may now tighten both with pliers.

Hold the Batteries

To keep the battery holder from dangling behind the robot, it should be attached to the chassis.

The four AA-size battery holder should be located under the bottom of the chassis to keep the center of gravity low. Locate the battery pack as close to the scoop as possible. Use double-sided tape to keep the battery holder in place (Figure 17). The nine-volt battery can be located between the scoop and the motors, inside the chassis.

If the battery is too large (size differs by brand), then use an alternate location. There is plenty of room on top of the motors, under the controller (Figure 18).

Doing Wheelies

The wheels are just as important as the scoop. Take good care of them. Mounting the wheels on the motor shaft is pretty simple. The shaft side is the side of the wheel with the bigger hole. The smaller hole is for inserting the screw that holds the wheel securely on the motor shaft. Once you have the wheels on, just place them on the axle and screw them in securely (Figure 19).

In any sumo competition, it is important to stand your ground. Ideally, you want your sumo to push and not be pushed. The difficulty lies in the fact that the plastic wheels have absolutely no grip.

A good and cheap solution to this problem is a "broccoli" tire. A "broccoli" tire incorporates the elastic band used to tie broccoli bunches in a grocery store.

For those who will buy their wheels (i.e., from **www.HobbyElectronics.com)**, the tires come bundled in the same package, at no extra cost. I find the matched, molded plastic wheels and tires to be a great value and convenience.

If you keep the tires clean, they will retain their traction for a long time.

Run, Sumo, Run

So, what do you do when you finish making your sumo-bot? For some, that can be a dilemma. You have many options. You can simply place it alongside your other completed projects on a shelf and hope no one ever asks you, "Why?" You can take it apart and start a new project from all the parts. You can even give it away for Christmas, hoping the recipient will know what to do with it.

I suggest you make your own competition ring (Figure 2) and test out your new mini-sumo. Of course, you need another person with a mini-sumo to challenge; this person will probably be more than happy to show off his "better" robot.

Ahoy, Mates!

You have a whole month to play with your rolling mini-sumo. Soon, we will take off the wheels and replace them with stilts (Figure 20).

In the next installment, moving along towards the ultimate robotics project (the A.R.M.), we are going to make "Peg-Leg," the walking robot. SV

About the Author

John Myszkowski worked in the area of electronics and mechanical design in the industrial automation and automotive industry for over 20 years, and loves tinkering. He can be reached through Email at john@myszkowski.net

Figure 20. In the next installment of "Cutting Edge" is Peg-Leg.

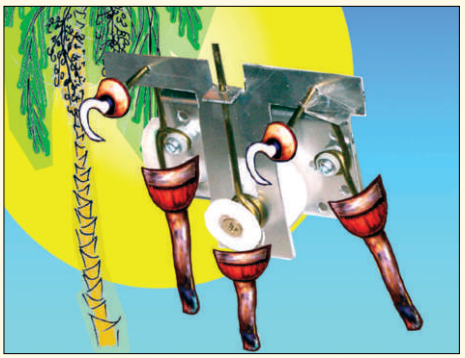
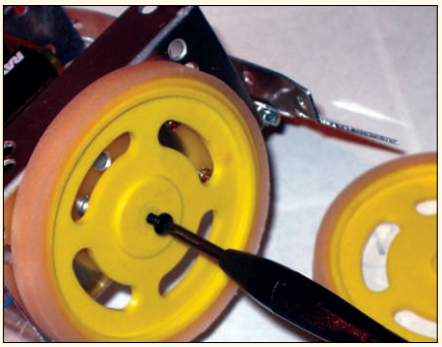
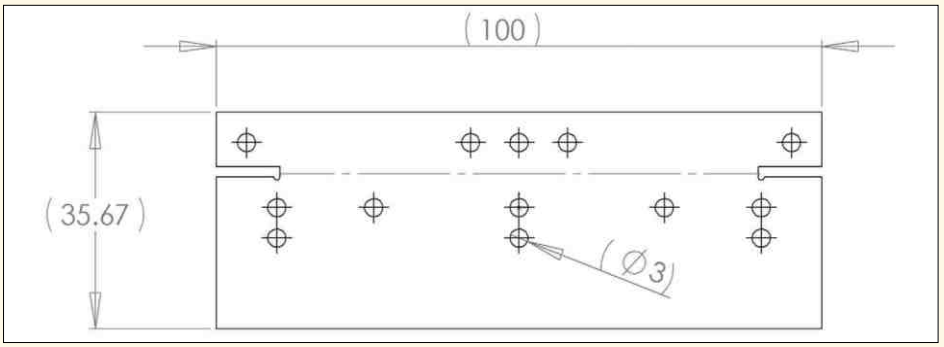


Figure 19. Attaching the wheels to the motor shaft.



Layout 1. Once printed at 100%, just paste the scoop layout to the metal, drill, cut and bend. All dimensions are in mm. Visit www.servomagazine.com for a digital image of this pattern.



Computer Interfaces For Robots

by Jan Axelson

EXPAND YOUR ROBOT'S ABILITIES WITH A WIRED OR WIRELESS LINK TO A REMOTE COMPUTER

For many robots, the ability to exchange information with a remote computer is useful or downright essential. A remote computer can request status information and send commands to configure and control the robot.

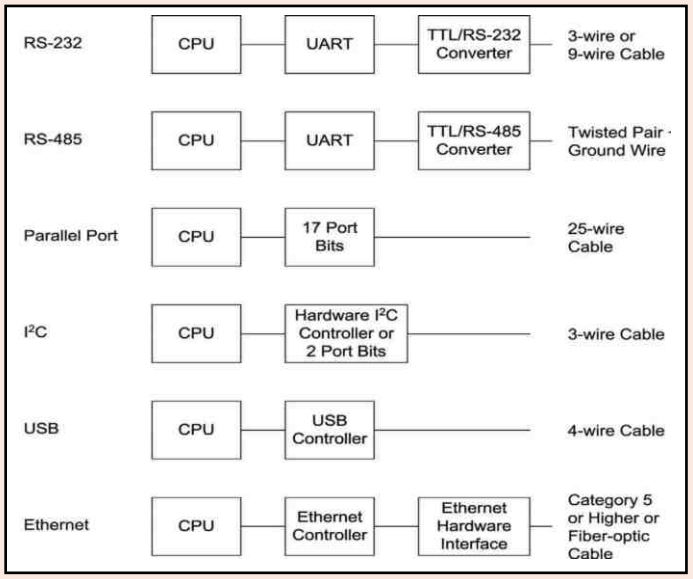
A computer that communicates with a robot can have a human operator or software that interacts with the robot with no human intervention required. A single computer can monitor and control multiple robots in varied locations. Robots that don't want to be physically tethered can use wireless interfaces. Some robots can receive their operating power from a computer interface.

Just about any robot can find a suitable interface for remote communicating. A link can be as basic as a few lines that connect port bits or as sophisticated as a wireless connection to the Internet. Some links don't even require the robot to have computer intelligence inside. For example, a remote computer can send signals that directly control a robot's motors or switches, and a basic timer circuit can cause a robot to send periodic status information. But with a microcontroller or other CPU inside, a robot can be programmed to send and receive much more detailed messages than a robot without a CPU can manage. This article explores the options for computer-controlled communications with robotic devices, including wired and wireless interfaces.

Wired Interfaces

Where it's feasible to run wires, a wired interface is usually the easiest and most inexpensive option. Most stationary robots and some mobile robots can use wired interfaces. Table 1 compares popular options that are suitable for robot communications, and Figure 1 shows the components required to implement each of the interfaces.

Figure 1. The required circuits between the cable and a robot's CPU will vary depending on the interface.



RS-232

For decades, RS-232 has been the workhorse for inexpensive communications over distances of 50 feet and more. All that's required is a UART (universal asynchronous receiver transmitter) and a chip or other circuit that converts between 5V logic and RS-232's positive and negative voltages. The PC's standard serial port is an RS-232 interface. A PC without an RS-232 port can use a USB/RS-232 converter. Many microcontrollers have an on-

chip UART, which converts between RS-232's serial data and the parallel data of the CPU's data bus. It's also possible to implement a UART in program code, as Parallax's BASIC Stamp does. For the hardware interface, you can use Maxim's MAX232 or a similar chip. A three wire cable is sufficient unless the robot needs additional handshaking lines. The RS-232 standard allows data rates of up to 20 kilobits per second, but some hardware supports faster speeds. An RS-232 interface can also connect to a modem for remote communications over phone lines.

RS-485

If RS-232 can't do the job because you need more distance, a faster data rate, or the ability to communicate with multiple robots, RS-485 is an option. An RS-485 interface typically uses a UART and a TTL/RS-485 interface chip that converts the UART's transmit and receive lines to RS-485's differential signals. Converters for RS-232 ports are also available.

An RS-485 network can have up to 32 unit loads. A unit load is a measure of a receiver's input resistance. If you have a lot of robots to control, Maxim's MAX3088 transceivers are a fraction of a unit load and allow up to 256 nodes on a network. In a network with multiple drivers, only one driver should be enabled at a time. A UART's RTS output can control the transmit-enable input at each interface. An RS-485 network cable contains a single 120Ω twisted pair, plus a ground wire.

A link between just two devices can use a twisted pair for each direction. With two pairs, both transmitters can be enabled all of the time and you don't need a transmit-enable line or program code to control it. RS-485's maximum cable length is 4,000 feet and the maximum data rate is 10 Mb per second, but you can't have both at the same time. For example, at 1 Mb per second, the maximum cable length drops to around 400 feet.

Parallel Port

Over the years, the PC's parallel printer port has been pressed into service for all kinds of applications, including robot control. The port has been popular because you could count on every PC having one. Plus, the port offers 17 bits that applications can use for any purpose. With the introduction of USB, parallel ports are beginning to disappear from PCs. Still, for some applications, the port is a serviceable and inexpensive option. A robot's microcontroller can use generic I/O bits to interface to a PC's parallel port. For best results over longer distances, use an IEEE-1284-compliant cable, which places each signal line in a twisted pair with a ground return.

I2C

Another option suitable mainly for shorter distances is the I2C (Inter-Integrated Circuit) bus. I2C is a synchronous serial interface that requires three wires: data, clock, and ground. The data line is bidirectional and must connect to open-collector or open-drain outputs.

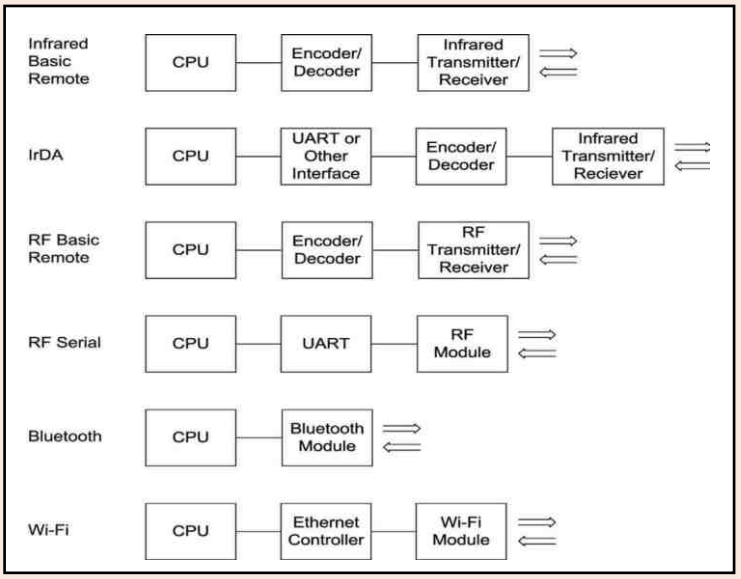
A few microcontrollers (such as Philips Semiconductor's PCB80C552) have a hardware I2C interface built in. The BL233 chip from **www.I2CChip.com** converts between asynchronous serial (such as a UART interface) and I2C. Or you can "bit-bang" available port bits to create the clock and read and write the data bits. An I2C bus can have up to about 40 devices, with the limit determined by a maximum bus capacitance of 400 pF. The maximum cable length is 18 feet, though you can exceed the limit with Philips' P82B715 I2C Bus Extender chips.

USB

The Universal Serial Bus (USB) is a multi-purpose interface that can connect PCs and Macs to mice, keyboards, printers, cameras, drives, and more, including robots. A USB host controls communications on the bus. Any PC or Mac of recent vintage can function as a USB host. An advantage to USB is the availability of bus power. A USB device can draw up to 500 milliamperes from the bus at a nominal +5V, so some robots with USB interfaces don't need on-board power supplies at all. Every USB device must contain a USB peripheral controller that responds to received USB requests and other events on the bus. Some microcontrollers have on-chip USB controllers, while others can interface to external controllers.

In the host computer, applications

Figure 2. Robots have a range of choices for wireless interfaces.



communicate with device drivers that, in turn, communicate with lower-level drivers that access the USB hardware. Descriptors stored in each USB device help the host identify which driver to assign to a device.A cable between a host and device can be up to five meters (three meters for low-speed devices). You can extend the distance to 30 meters using hubs. A USB cable is two twisted pairs (except for some low-speed devices where twisting the pairs is optional) and shielded.

Ethernet

The Ethernet network interface is powerful and fast, with popular bus speeds beginning at 10 megabits per second. A twisted-pair cable segment can be 100 meters, and fiber-optic segments can be up to 2,000 meters (or 2 kilometers if full duplex). Repeater hubs and switches can extend the distances further. And if that's not enough, you can connect the local Ethernet network to the Internet and make your robot available to anyone with access! For the cable, you can use standard twisted-pair Category 5 or higher cable, or fiber-optic cable. To use Ethernet, a robot must have an Ethernet controller (typically, a dedicated chip), a hardware interface for the cable, and program code to enable the CPU to communicate with the controller. Most Ethernet communications use Internet protocols such as TCP/IP, so most Ethernet-capable devices support these, as well. To make the job of Ethernet communications easier, a variety of vendors offer modules that each contain a CPU, Ethernet controller, and programming libraries to support Ethernet communications and Internet protocols. Two examples suitable for robot applications are Dallas Semiconductor's TINI modules and Rabbit Semiconductor's RabbitCore modules (see Peter Best's article in the January 2004 issue of *Nuts & Volts*). PCs that don't have Ethernet support can use USB/Ethernet adapters.

Going Wireless

Any data link has to be able to carry information at the desired speed, without errors, and without causing interference or other problems in nearby circuits. For many applications, wired interfaces meet these requirements easily and at low cost. But for some applications, stringing cable is expensive, inconvenient, or impossible.

Mobile devices can move about more easily if not tethered to cables.

Some wireless links can communicate through walls and ceilings. Short-range, line-of-sight wireless links can use beamed infrared (IR) energy. For longer distances, communicating beyond the line of sight, or other situations where infrared isn't practical, modulating information onto radio-frequency (RF) waves is an alternative.

If using RF, you need to take care to comply with the rules and regulations for the Federal Communications Commission (FCC) in the US and similar agencies in other countries. In the US, a device that is for sale and emits RF must be tested and assigned an FCC number.

Table 2 shows popular wireless interfaces suitable for robot communications,

Table 1. All of these wired interfaces are suitable for robotics.

Interface	Maximum Distance (ft)	Maximum Bit Rate (bits/sec)	Cable Type	Supporting Components	Typical Use
RS-232	50-100	20K (higher with some drivers)	3, 9, or 25 wires	UART, RS-232 transceiver	Any devices with UARTs
RS-485	4,000	10M	3 or 4 wires and ground	UART, RS-485 transceiver connection	Industrial networks and long distances
Parallel Port	10-30	8M	25 wires	17 port bits	Short links to PCs, inexpensive
I2C	18	3.4M	3 wires	2 port bits (one open-drain)	Microcontroller networks
USB	16 (96 with hubs)	1.5M/12M/480M	4 wires, shielded	USB peripheral controller	Links to PCs, bus-powered devices
Ethernet	330 (twisted pairs) 6,500 (fiber optic), more with hubs or full duplex	10M/100M/1G/10G	2 twisted pairs (4 pairs for 1 Gbps) or 2 fiber optic strands	Ethernet controller	Links or networks over long distances and at high data rates

and Figure 2 shows the components required to implement each interface.

Infrared Basic Remote

For low data rates over short distances, an inexpensive option is an infrared transmitter that sends encoded address and data information to an infrared receiver module. Encoder/decoder chips from Holtek and others help the receiver detect valid data. A typical encoder has address and data inputs. On receiving a transmit-enable pulse, the chip outputs the encoded address and data information multiple times in sequence. The number of address and data inputs, and the number of repetitions vary with the encoder chip. An oscillator provides a 38- or 40-kHz carrier, and a logic gate modulates the carrier with the encoder's output. Modulating the data onto a carrier helps the receiver filter out extraneous IR signals and detect only the transmitted data. The resulting signal drives an infrared-emitting diode. At the other end, an infrared receiver module detects and demodulates the data, and a decoder chip reads the result. If the received address matches the decoder's address and repeated transmissions are identical, the decoder makes the data available on its output pins. This type of interface works well for line-of-sight links over distances of up to about 15 feet. Lenses can focus or broaden the infrared beam if needed. These links are slow due to the inclusion of address bits, repeated data for error-checking, and limitations of IR detectors. Four data bits typically require around 100 milliseconds to transmit. This rate is plenty fast for some applications, however. The components are available from a variety of sources, including Digi-Key. Reynolds Electronics has kits, assembled boards, and components for infrared links.

IrDA

Another option for infrared communications is the Infrared Data Association (IrDA) interface. The maximum distance is about four meters. For many applications, the easiest way to implement an IrDA link is to interface to a UART. Microchip Technology's MCP2120 Infrared Encoder/Decoder can provide the needed encoding and decoding. Devices with RS-232 ports can use an RS-232/IrDA converter such as Actisys' ACT-IR220Li. This converter gets its power from the RS-232 port, which limits the range to 2.4 meters. Another option for serial infrared links is Reynolds Electronics' TX-IRHS infrared transmitter chip, for use in links of up to 19,200 bits per second.

RF Basic Remote

For links at low data rates where infrared isn't practical, you can send data in an RF link using encoder and decoder circuits similar to those used in IR links. These links typically use a frequency band reserved for sending brief, occasional commands or control information. Popular frequencies are 315, 418, and 433 MHz. Garage-door openers and other keyless entry systems use the band, and robots can use it, as well. These links can

Table 2. These wireless interfaces use infrared or radio-frequency (RF) technologies.

Interface	Maximum Distance (feet, typical, indoors)	Maximum Bit Rate (bits/second, typical)	Transmission Method	Supporting Components	Typical Applications
Infrared Basic Remote	15	36 (nine 4-bit words)	infrared	Encoder/decoder, IR transmitter and receiver	Sending basic commands, status commands, and basic information, line-of-sight
IrDA	13	16M	infrared	UART or other interface, encoder/decorder, IR transmitter/receiver	Any data over short, line-of-sight links
RF Basic	500	40 (10 4-bit words)	RF	Encoder/decoder, RF transmitter and receiver modules	Sending basic commands and status information
RF Serial	1,500	50K	RF	UART, RF	Any data, long-distance links
Bluetooth	33	1M	RF	Bluetooth module	Links to PCs, short distances
Wi-Fi	150	54M	RF	Ethernet controller, Wi-Fi	Communicating with Ethernet

transmit up to around 500 feet. For this band, FCC regulations specify not only the maximum permitted field strength for transmissions, but also the amount of time the transmitter can be on continuously and even permitted applications. For example, you can use the band to communicate with "toys" only at reduced power.

The relevant part of the FCC rules is Title 47, Part 15.231. Some modules use the Industrial, Scientific, and Medical (ISM) band of 902 to 928 MHz, which doesn't have the same limitations. Sources for RF remote modules include ABACOM Technologies, Circuit Specialists, HVW Technologies, Linx Technologies, Ramsey Electronics, Reynolds Electronics, and RF Digital Corporation.

RF Serial

For RF links that need more capability than a basic remote, modules that interface to UARTs are available. These use the ISM bands of 902 to 928 MHz and 2.4 GHz. Many cordless phones use these same bands.

Data rates of up to 50 kilobits per second and distances of up to 1,500 feet are possible. Sources for modules include Abacom, MaxStream, and RF Digital Corporation.

Bluetooth

Bluetooth is a more recent option for RF communications over distances of up to 10 meters. The interface was designed to be fast, low power, and reliable. The data rate is 1 Mb per second. Transmission uses the 2.4 GHz band. To support Bluetooth, a device must contain a CPU with a Bluetooth interface or a Bluetooth module that interfaces to a UART or other port on the device's CPU. Development kits are on the expensive side, though prices will probably drop in time. Sources include National Semiconductor and Ericsson. Another option is a Bluetooth/RS-232 converter, which enables any device with an RS-232 interface to use Bluetooth. PCs can support Bluetooth with an expansion card or adapter module.

Wi-Fi

Wi-Fi (wireless fidelity) refers to RF networks that transmit at 11 or 54 Mb per second, as defined in IEEE standards 802.11b and 802.11g. The networks use the 2.4 and 5 GHz bands. A robot or other computer with an Ethernet interface can add Wi-Fi with a connection to an Ethernet/Wi-Fi bridge or access point, available from Linksys and other vendors. Ubicom offers an Advanced Wireless Kit for developing applications that use Ubicom's wireless network processors. The kit includes a PC (PCM-CIA) card that adds support for 802.11b Wi-Fi.

Fans of Microchip's PICMicro microcontrollers should look into the ChipWeb Wireless development kit from IoSoft, Ltd. The kit includes a PIC18F452 microcontroller, an RTL8019AS Ethernet controller, an IEEE 802.11b wireless PC Card and interface, and C source code for Wi-Fi communications.

So Many Options ...

Although there are plenty of interfacing options, the needs of a particular application should help to narrow the selection. Use a wired interface unless wireless offers a clear benefit.

Then select the simplest option that meets your robot's needs for distance and data rate. SV

Author Bio - Jan Axelson is the author of four books on computer interfacing, including *Embedded Ethernet*, *Internet Complete*, and *USB Complete*. Jan's website at **www.Lvr.com** is devoted to the topic of computer interfaces.

SOURCES

ABACOM Technologies
www.abacom-tech.com

Actisys
www.actisys.com

Circuit Specialists, Inc.
www.circuitspecialists.com

Dallas Semiconductor
www.dalsemi.com/TINIplatform.cfm

Digi-Key
www.digikey.com

Ericsson Inc.
www.ericsson.com/mobilityworld

Holtek Semiconductor Inc.
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HVW Technologies
www.hvwtech.com

I2CChip.com
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Rabbit Semiconductor
www.rabbitsemiconductor.com

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www.rentron.com

RF Digital
www.rfdigital.com

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Let the Games Begin

by Chris Gilleski

Ever since the rise of robotic combat, the sport has faced harsh criticism from many fronts, often quite similar criticism from quite different groups. Robotic purists see combat robots as little more than toys, similar to criticism leveled against it by many in the general public who grew tired of it quickly. As you delve deeper into the arguments against combat robotics, many seem quite sound. So, let us take a different look at the nature of robotic combat and the philosophy behind their construction.

You can't use the imperfect as a measure of anything — though people are sometimes content with it, and don't want to look further.

This quote from Plato's *Republic* is especially interesting with regards to robot combat. Luckily, we do not live in Plato's republic. In such a society, "sport" such as robotic combat would be outlawed completely, but much of Plato's philosophy gets to the heart of the issues of striving for a greater good, and a greater excellence, something that is often lacking in combat robotics.

One of the most widespread criticisms of these robots is the prevalence of wedges, and the general stagnation of designs seen on television. Many combat robot builders in the past have been satisfied to trot out the same old design with a few minor tweaks, seemingly content with the imperfections of their robot and having no desire to challenge themselves. In both of the major combat robotics shows that hit the American airwaves two years ago, audiences witnessed what was to them incredible new technology, and were drawn in by the novelty of the robots. But as time went on and the robots failed to change, the audience drifted away.

Why would a branch of robotics fail in this area, when robotics in general has always been a showcase of new ideas and new technology? One can look as NASA's Mars rover as an example of this ever expanding and intriguing technological evolution. The last Mars probe captivated the American public once again because the technology was so new and so incredible to the general public. Now as we stand so close to another Mars rover landing on the planet, the technology involved has grown by leaps and bounds and looks to once again capture the fickle public's imagination. But if you left it up to the public's view of a stereotypical combat robot builder, all that would be changed on the Mars Rover is a new weapon attachment, and possibly a new paint scheme. This, of course, is not the case, but perceptions can easily be reality when it comes to a potential fan base.

The fact of the matter is until recently, combat robotics promoted the type of behavior that Plato describes. With little incentive to build anything new, and many incentives to trot out the same warhorse, Battlebots™ featured mostly the same robots from season to season with only one or two new interesting robots showing up each year. Since the advent of nationwide competitions, this has changed, and new robots have begun popping up at an astounding rate. Of course, this has been done away from the public eye so the mindset that combat robots are just simplistic toys remains because many have seen no evidence to the contrary.

And what are we to suppose the philosopher thinks of other pleasures compared with that of knowing the truth and being always engaged in pursuit of it?

From its conception until the first major legal woes, combat robotics existed almost as the ideal of Plato's philosopher king. Groups of people who dedicated their time and money to the goal of knowledge, and created interest in a branch of knowledge. While winning was a goal, it was not the ultimate goal. Most competitors shared a common goal of learning through their machines, to create unique, interesting designs that would please the eye and challenge the imagination. There were no incentives to cart out the same design year after year; so many competitors brought back radically different robots each year, while others came back with improved versions of earlier robots.

But with the end of Robot Wars in the United States, and the Battlebots television deal, this attitude seemingly changed. Robots began being brought back event-after-event, and more than ever, innovation seemed stagnant. This is not to say that the competitors suddenly decided to stop challenging themselves and pursuing knowledge, and instead became only interested in cashing in on their old robot's image. Rather, the incentives existed that many would be foolish to scrap an old recognized robot which could get them television and toy royalties each year in favor of a new design which

might not even get close to getting on television. This influx of money into the sport sadly acted as a stranglehold on some of the best aspects of combat robotics, and turned a group of people engaged in a search for knowledge through fighting cool new technology into a group of people fighting similar technology repeatedly.

But with the end of major television deals for American competitions, the stagnation that caused the world to get bored with combat robotics has vanished. The past year has seen the creation of more new events, more weight classes, and an increase in new designs and innovations replacing older robots. Many have said that the robots seen on Battlebots would never survive against the new breed of robots in today's competitions, and this would seem to be true. Where for years the same robots could win time after time with few changes, now in the course of one year they are simply obsolete.

That is not to say that all is right with combat robotics. There is still a glut of "me too" designs where cloning seems to take the place of originality. There are still many robots that are built not to strive for knowledge or to test one's abilities, but instead to win. But despite the shortcomings of some, the sport continues to make huge strides as it approaches its 10 year anniversary in the summer of 2004. Once again, builders are following not only the philosophy taught by Plato, but the philosophy that has been vital to the field of robotics since its inception.

We have once again embraced the pursuit of knowledge, and the desire to challenge ourselves and the imagination of others, two elements that are vital to combat robotics acceptance not only in mainstream America, but also to those in the other avenues of robotics. **SV**

Author Bio

Chris Gilleski is a notoriously outspoken member of the combat robotics community, and former antweight division champion. In addition to robotics, he is currently majoring in philosophy and political science at the University of Connecticut, and is a teaching assistant for third grade classes.

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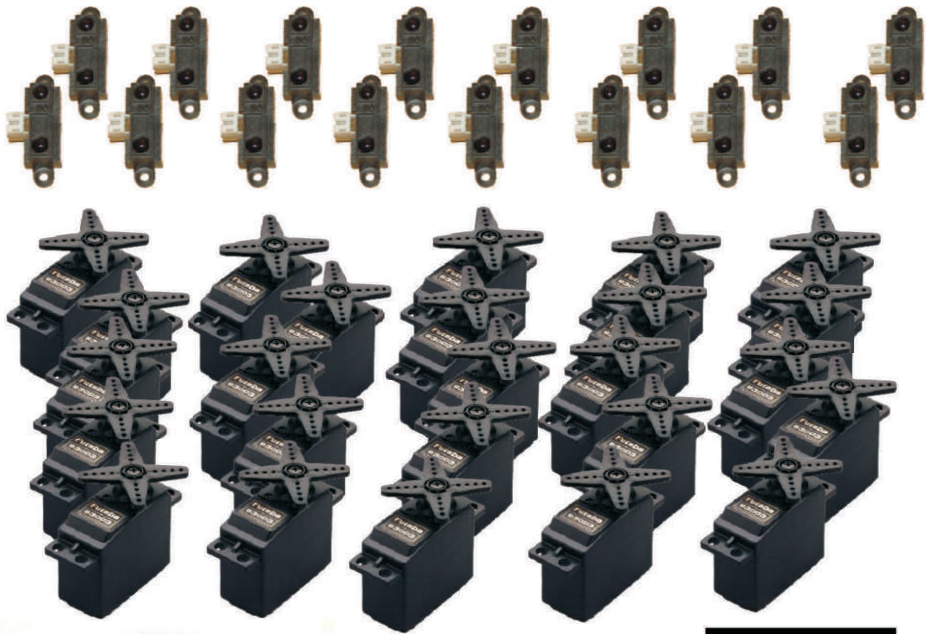

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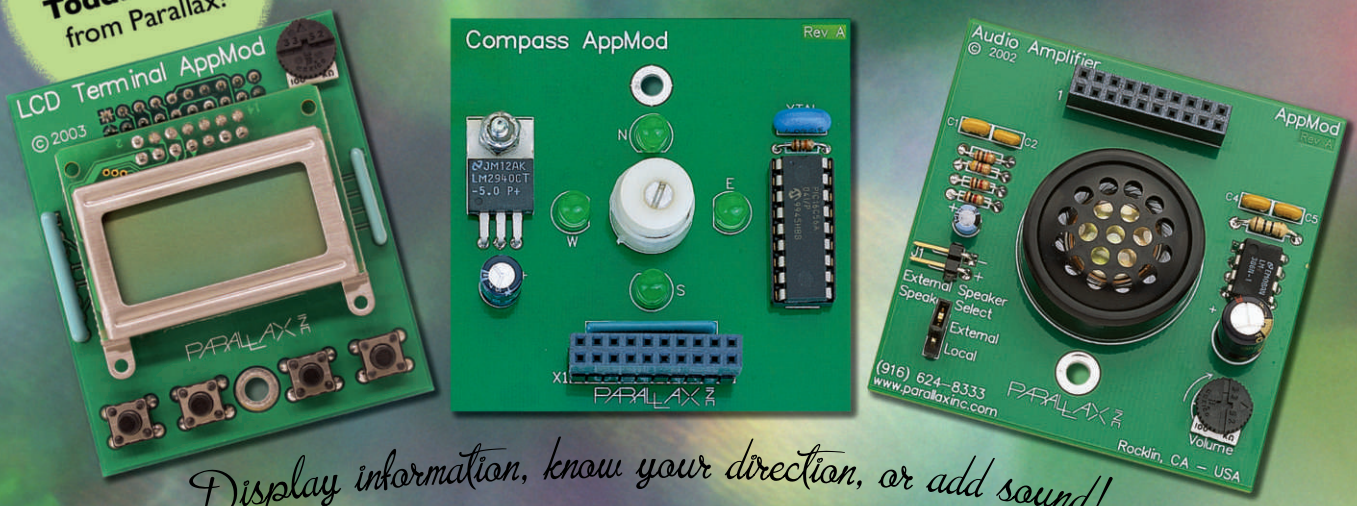

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